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THE INFLUENCE OF VARIATION OF TEMPERATURE OF WATER ON THE DEVELOPMENT OF FISH-EGGS. II.

By

Minoru Kawajiri.

In a previous paper[1], I reported on the influence of variation of temperature on the development of the eggs of *Leuciscus hakuensis* and *Carassius auratus*. I had opportunity to make a similar experiment on the eggs of *Salmo irideus*, Gibbons.

Parent fishes were caught in a pond at Kizaki Fish-cultural Station, Imp. Fish. Inst.; Prefecture Nagano. The ripened eggs and sperms taken from them were artificially mixed up by the dry method, and every 25 eggs was put in each cup filled with about 100 c.c. of water. Then the cups were placed one by one into 10 dark chambers of a thermostat* which was regulated to maintain a series of 10 constant temperatures.

The cups were interchanged to each other once a day, in the following way: No. 1 with No. 10, and No. 2 with No. 9 and so on, so as to change the temperature of cups repeatedly from low to high and *vice versa*. Besides these 10 cups I prepared another set of 10 cups for control and kept them in the same thermostat without changing their position during the experiment, so as to give a constant temperature continuously for each of them. As another control, the remaining eggs were put in a hatching apparatus supplied with running water.

The details of the experiment for the two sets of the control kept without the changing of temperature are given in Tab. A. The hatch-rate and hatching-days calculated from the data in Tab. A are given in Tab. I. Fig. 1 shows the relation between the hatch-rate and the temperature of water and Fig. 2 shows that between the hatching-days and the temperature.

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(1) M. Kawajiri: The influence of variation of temperature of water on the development of fish-eggs. (Jour. Imp. Fish. Inst. XXIII, 3, 65-73, 1927).

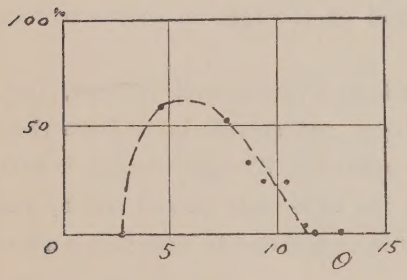
* Senō, H. and Tauti, M.: Apparatus for maintaining a series of constant temperature. (Jour. Imp. Fish. Inst. Vol. XX, No. 4, 1925).

Table I. Hatch-rate and hatching-days at various temperature.

No.	1	2	3	4	5	6	7	8	9	10	C
Mean temperature °C	12.9	11.7	11.3	10.4	9.3	8.7	7.7	6.5	4.5	2.8	11.5
Mean variation °C	0.5	0.6	0.7	0.6	0.7	0.7	0.7	0.7	0.8	0.7	0.3
Number of eggs used	25	25	25	25	25	25	25	25	25	25	1,223
Number of hatched fry	0	0	1	6	6	8	13	2	15	0	735
Hatch-rate %	—	—	4	24	24	32	52	0.8	60	—	60.1
Number of deformities	—	—	2	0	0	0	0	0	0	—	7
Ditto, % to hatched fry	—	—	33	0	0	0	0	0	0	—	0.95
Mean hatching-days	—	—	30.0	32.1	35.0	40.3	46.5	57.5	72.9	—	30.3

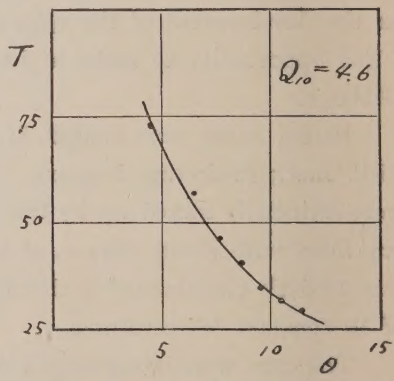
Remarks: "C" is the control lot supplied with running water.

Fig. 1.



Graph showing the relation between the hatch-rate and the temperature
•.....Hatch-rate
θ.....Water temperature.

Fig. 2.



Graph showing hatching-days and temperature.
T.....Hatching-days
θ .....Water temperature.

Comparing the results stated just above and the results given in the paper on the optimum temperature of water for hatching of eggs of *Salmo irideus*[2], we see that the hatch-rate in the former case is poorer than that in the later. This difference may be supposed to be due to the quality of eggs.

The details of the experiment kept under the varying temperature are given in Tab. B. The hatch-rate and hatching-days calculated from the data in Tab. B are given in Tab. II.

From Tab. II, Figs. 1 and 2 we can calculate the ratio of the hatch-rate under changing temperature to that under constant temperature in case the mean value of temperature remains the same; so also for the ratio of hatching-days.

(2) M. Kawajiri: On the optimum temperature of water for hatching the eggs of rainbow trout. (Jour. Imp. Fish. Inst. Vol. XXIII, No. 3, 1927).

Table A

Date.	Number of days.	1	2	3	4	5	6	7	8	9	10	C
31/III	1											11
3/IV	4	1										20
4	5											5
6	7											19
8	9		1						1			
9	10								1			17
10	11	2										
11	12	4	1									19
12	13	1										
13	14	2	1			1						9
14	15	2										
15	16	11	1	1								
16	17	1	1								1	14
17	18	1	1	1								
18	19											20
19	20		2									
20	21		6						15			18
21	22		3						5			18
22	23		6	1								8
23	24		2	1								10
24	25											292 (1)
25	26										1	
26	27											(2)
27	28			1							6	(1)
28	29						1			1	1	(11)
29	30			4(1)							1	(504)
30	31			3	(1)							(197)
1/V	32			2	6(3)							8(18)
2	33			6	8(2)	1					1	(1)
3	34			4	5	2						
4	35					3(6)						
5	36					4	1					
6	37					2	1				1	
8	39					6	1(2)					
9	40						2(4)					
10	41										1	
11	42						3(2)					
12	43						2	1			1	
13	44						3				2	
14	45						3				1	
15	46							1(6)		1	2	
16	47							1(7)			2	
17	48							2				
19	50							2			1	
20	51							3		1		
21	52							1				
23	54									1		
26	57								(1)			
27	58							1	1(1)			
30	61									1	1	
2/VI	63										1	
4	65									1		
10	71									1		
11	72									1(5)		
12	73									(8)		
13	74									(1)		
15	76									1(1)		
21	82									1		
2/VII	93										1	
Total		25(0)	25(0)	24(1)	19(6)	19(6)	17(8)	12(13)	23(2)	10(15)	25(0)	488(735)

C....Control lot applied with running water.
Numerals....Number of dead eggs; Numerals in brackets....Numbers of hatched fry.

Table B

Date	Number of days	1		2		3		4		5		6		7		8		9		10	
		h.	l.	h.	l.	h.	l.	h.	l.	h.	l.	l.	h.	l.	h.	l.	h.	l.	h.	l.	h.
4/IV	5	1																			
8	9	1																			
9	10																				1
10	11	1		1		1															
11	12	1																		1	
12	13																		1		
14	15	2																			
15	16		2																		2
17	18										1										
19	20																				1
20	21																			1	
21	22												1								
22	23	1																			
26	27	1																			
27	28										1										
29	30																1		1		
30	31	3																			
I/V	32		1										1				1				1
2	33	1																1			
3	34				1														2		1
4	35	1										1				1					
5	36				2																
6	37	1				1		1		1						1				1	
7	38		3		1		(2)		3(3		(9)		(6)		(3)				1		
8	39	1(1)		1(2)		5(6)		7(4)		1(1)		6(6)		3(8)				1			
9	40				1(6)		1(1)		2		1(1)		1(2)		4(1)		4(5)		(4)		2
10	41	1(2)		3		6		2(1)		4		1		1		3(2)		1(3)		2(1)	
11	42				1		1		1		5				2(1)		2(1)		7		(1)
12	43			4		1		1						1		4				(1)	
13	44				1										1						2(1)
14	45			1														2(1)		3	
15	46																				3
Total		16(3)	6	10(2)	7(6)	14(6)	2(3)	11(5)	6(3)	6(1)	8(10)	8(6)	3(8)	5(8)	7(5)	9(2)	8(6)	5(4)	12(4)	8(2)	13(2)

Numerals....Number of dead eggs; Numerals in brackets....Number of hatched fry.
h....high temperature bath. l....low temperature bath.

Table II.

No.	1	2	3	4	5
Mean temperature °C	7.1	7.8	8.7	8.8	8.8
Mean variation	5.5	4.0	2.4	1.5	0.7
Number of eggs used	50	50	50	50	50
Number of hatched fry	7	17	17	21	25
Hatch-rate %	14	34	34	42	50
Number of deformities	4	2	3	1	5
Ditto, % to hatched fry	29	6	9	2	10
Mean hatching days	41.6	40.2	39.6	39.0	38.5

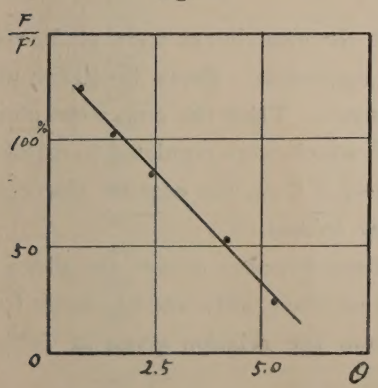
Tab. III and Figs. 3 and 4 show the effect of the mean variation of temperature on the ratio of the hatch-rate and also on the ratio of the hatching-days, just referred to.

Table III.

No.	1	2	3	4	5
Mean temperature °C	7.1	7.8	8.7	8.8	8.8
Mean variation °C	5.5	4.0	2.4	1.5	0.7
Hatch-rate at varying temperature (F)	14	34	34	42	50
Calculated hatch-rate at constant temperature (F')	56	52	41	40	40
$\frac{F}{F'} \times 100$	25	65	83	102.5	125
Hatching-days at varying temperature (T)	41.6	40.2	39.6	39	38.5
Calculated hatching-days at constant temperature (T')	50	46	41	40	40
$\frac{T}{T'} \times 100$	83	87	97	97	96

In Figs. 3 and 4 we see that the ratios of hatch-rate and of hatching-days

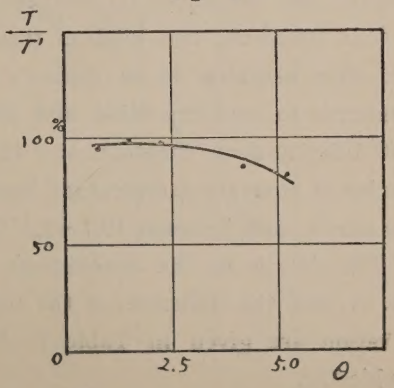
Fig. 3.



•....$\frac{F}{F'} \times 100$

θ....Mean variation of temperature.

Fig. 4.



•....$\frac{T}{T} \times 100$

θ....Mean variation of temperature.

decrease as the mean variation of temperature increases, and we know that the eggs of *Salmo irideus* are influenced by the variation of temperature in the same manner as those of *Leusiscus hakuensis* and *Carassius auratus*.

Summary.

When the mean temperature remains the same, the hatch-rate and the hatching-days of eggs of *Salmo irideus*, Gibbons decrease as the mean variation of temperature increases.

July, 1928.

Kizaki Fish-cultural Experiment Station,
Imp. Fish. Inst.

ON THE RELATION OF GROWTH AND DEATH FROM STARVATION OF THE TROUT FRY TO TEMPERATURE.

By

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The present study has been done to know how growth and death from starvation of the trout fry (*Oncorhynchus nerka*, Brevoort. and *Salmo irideus*, Gibbons.) are influenced by temperature.

The fry of the two kinds of trout used for the experiment were at the stage soon after hatching in an Attkin's hatching apparatus. Every 8～10 fry were transferred to each cup filled with 100 c.c. of water. Then the cups were placed in 10 different dark chambers of 2 thermostats* which were regulated to maintain a series of constant temperature between 16.4～2.5° C in the case of *Oncorhynchus nerka*, and between 19.7～1.2° C in *Salmo irideus*.

The details of the experiment on the *Oncorhynchus nerka* are given in Tab. A, and the influences of the temperature on the growth and on death from starvation are given in Table I. Fig. 1 shows the relation given in Table I graphically.

* Senō, H. & Tauti, M.: Apparatus for maintaining a series of constant temperature (Jour. Imp. Fish. Inst. Vol. XX, No. 4, 1925).

Table A.

Date.			Number of days.	1	2	3	4	5	6	7	8	9	10
28	1	1927	6	r									
1	2		10		r								
7			16			r							
10			20				r						
13			23					r					
23			33	a									
25			35	1					r				
27			37		a								
8	3		46			a				r			
13			51	1			a						
15			53	2	1			a					
16			54	1	2								
17			55	1									
18			56		2								
25			63			1							
28			66						a		r		
6	4		75			2							
9			79			1	1						
14			83							a		r	
20			89					1					
21			90				1				a		
23			92					1					
25			94					1	2				
27			96						1				
28			97					2					
29			98						2				
1	5		100					1	6			a	
2			101					1					
18			117							1			
21			120							1			
23			122							1			
24			124							4			
5	6		135								1		r
10			140								1		
12			142								1		
9			149										
30			160									1	a
4	7		164									1	
6			166										1
8			168									1	
9			169									1	
10			170									1	1
8	8		199										1
9			200										1

Remarks: "r" is the beginning period of rising up of the fry.
"a" is the period of entirely absorbed the yolk sac.
The numeral is the number of dead fry.

Table I.

No.	1	2	3	4	5	6	7	8	9	10
Mean temperature °C	16.4	14.5	12.7	11.9	10.6	9.2	8.0	6.6	5.0	2.5
Mean variation °C	0.6	0.6	0.7	0.7	0.8	0.8	0.9	1.2	1.5	0.6
Number of days taken for rising up	6	10	16	20	23	35	46	66	83	135
Number of days taken for absorbing yolk sac	33	37	46	51	53	65	83	90	100	145
Mean number of days taken for starving to death	50.1	54.6	73.0	84.5	95.7	98.2	122.1	139.0	166.2	183.7
Number of fry used	6	5	4	2	7	11	7	3	5	4
Period of time in which fry starve to death	35–55	53–56	63–79	79–90	89–101	94–100	117–124	135–142	160–170	166 200

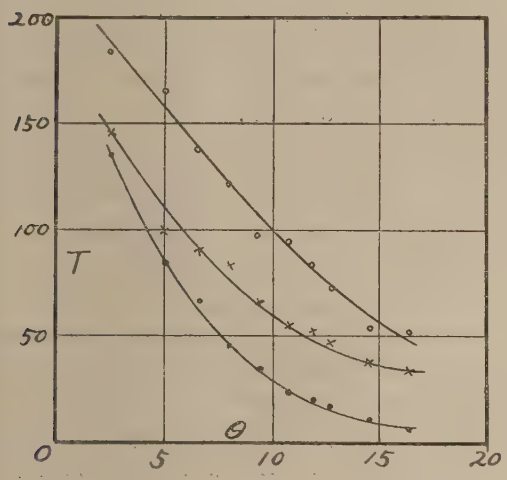


Fig. 1.

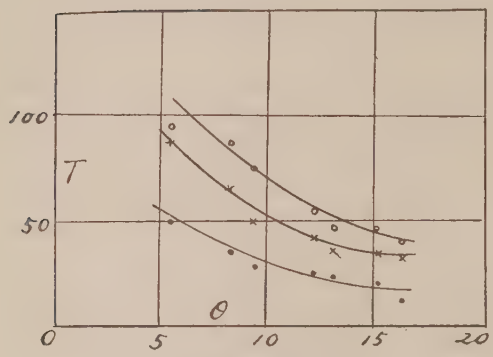
θ ....Water temperature.
T....Number of days.
• ....Rising up.
×....Absorption of yolk sac.
∘ ....Starvation.

The details of the experiment on *Salmo irideus* are given in Table B, and the influences of temperature on growth and on starvation are given in Table II. Fig. 2 shows the relation given in Table II graphically.

Table II.

No.	1	2	3	4	5	6	7	8	9	10
Mean temperature °C	19.7	17.3	16.3	15.1	13.2	12.1	9.3	8.3	5.6	1.2
Mean variation °C	1.4	1.1	0.6	0.6	0.6	0.6	0.7	0.6	0.5	0.4
Number of days taken for rising up	—	—	17	20	24	26	29	36	50	—
Number of days taken for absorbing yolk sac	—	—	32	34	37	41	50	66	88	—
Mean number of days taken for starving to death	—	—	40.0	46.9	46.4	53.3	75.6	89.2	95.4	—
Number of fry used	—	—	8	9	10	8	7	7	6	—
Period of time in which fry starve to death	—	—	34–44	36–60	38–60	44–64	64–85	83–90	94–98	—

Fig. 2.



θ ....Water temperature.
T....Number of days.
• ....Rising up.
× ....Absorption of yolksac.
° ....Starvation.

Previously, T. Higurashi and M. Tauti[1], S. Ueda[2], J. Hori[3] and M. Kawajiri[4][5] studied the relation between the temperature and the growth or vitality of several kinds of organisms and expressed the relation by the following formula:

$$Te^{a\theta}=C.$$

Where T is the duration of time at θ° C, and a and C are some characteristic constants. Accordingly, we may suppose that the same formula holds for the relation between the temperature and the time during which the trout fry grows to a definite stage or starves to death.

Table III, Figs. 3 and 4 show the relation between the temperature and the time during which the trout fry absorbs the yolk sac entirely, or starves to death

Table III.

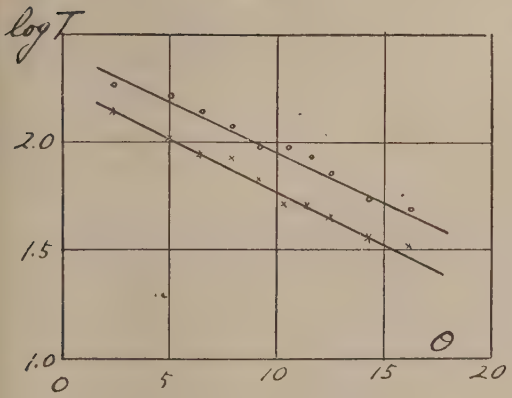
	No.	1	2	3	4	5	6	7	8	9	10
Oncorhynchus nerka.	Mean Temperature °C	16.4	14.5	12.7	11.9	10.6	9.2	8.0	6.6	5.0	2.5
	Number of days taken for absorbing yolk sac (T)	33	37	46	51	53	65	83	90	100	14.5
	log T	1.52	1.57	1.66	1.71	1.72	1.82	1.92	1.95	2.00	2.16
	Calculated value of T	34.5	38.0	45.7	50.1	57.6	66.0	75.7	86.6	104.5	138.0
	Mean number of days taken for starving to death (T')	50.1	54.6	73.0	84.5	95.7	98.2	122.1	139.0	166.2	183.7
	log T'	1.70	1.74	1.86	1.93	1.98	1.99	2.09	2.14	2.22	2.26
	Calculated value of T'	46.7	59.8	71.9	78.0	89.6	104.0	117.8	136.5	163.0	208.0
Salmo irideus.	Mean temperature °C	19.7	17.3	16.3	15.1	13.2	12.1	9.3	8.3	5.6	1.2
	Number of days taken for absorbing yolk sac (T)	—	—	32	34	37	41	50	66	88	—
	log T	—	—	1.51	1.53	1.57	1.61	1.70	1.82	1.94	—
	Calculated value of T	—	—	30	33	40	44	58	64	82	—
	Mean number of days taken for starving to death (T')	—	—	40.0	46.9	46.4	53.3	75.6	89.2	95.4	—
	log T'	—	—	1.60	1.67	1.67	1.73	1.88	1.95	1.98	—
	Calculated value of T'	—	—	39.1	43.4	51.2	56.4	67.3	78.7	99.5	—

Table B.

Date.			Number of days	1	2	3	4	5	6	7	8	9	10
13	5	1928	17			r							
16			20				r						
22			24					r					
24			26						r				
27			29							r			
30			32			a							
1	6		34			1							
2			35				a				r		
3			36				1						
4			37					a					
5			38					2					
6			39			3		2					
8			41			2			a				
9			42				2						
10			43			1	2						
11			44			1			3				
13			46					2					
16			49				2	2					
17			50						1	a		r	
24			58				1		2				
27			60				1	2					
1	7		64						2	1			
3			66								a		
11			73							2			
12			74							1			
17			79							1			
21			83								1		
23			85							2	2		
26			88								2	a	
1	8		94									2	
2			95								1	2	
3			96									1	
5			98									1	
7			90								1		

Remarks: "r" is the beginning period of rising up of the fry.
"a" is the period of entirely absorbed the yolk sac.
The numeral is the number of dead fry.

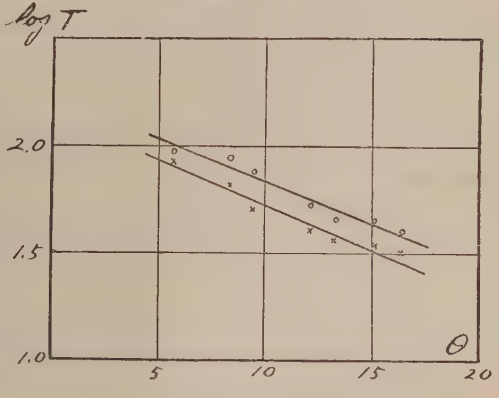
Fig. 3.



Oncorhynchus nerka.

θ .....Water temperature
log *T*....Logarithm of number of days.
×.....Absorption of yolk sac.
∘ .....Starvation.

Fig. 4.



Salmo irideus.

θ .....Water temperature
log *T*....Logarithm of number of days.
×.....Absorption of yolk sac.
∘ .....Starvation.

From the Figs. 3 and 4 we know that the relation between T and θ is expressed by the formula stated above.

By the formula we obtain the values shown in Table IV.

Table IV.

	Oncorhynchus nerk.				*Salmo irideus.*			
	a log e	*C*	*a*	Q_{10}	*a log e*	*C*	*a*	Q_{10}
Absorption of yolk sac	0.046	352	0.107	2.90	0.042	141	0.096	2.61
Stavation to death	0.046	386	0.105	2.85	0.038	162	0.087	2.40

Befor closing the paper, I wish to express my sincere thanks to Dr. M. Tauti for his helpful advice and also to Mr. T. Maruyama for his kind assistance during this experiment.

Summary.

1. If we keep the fry of *Oncorhynchus nerka* or *Salmo irideus* in different temperatures of water without supply any food matter, the duration of time taken for rising up, the period taken for absorbing the yolk sac, and the number of days of starving to death become shorter as temperature rises.

2. This relation may be expressed by the formula $Te^{a\theta}=C$, in which T is the duration of growth or the number of days taken for starving to death at θ° C, and a and C are the characteristic constants of the trout; and temperature coefficient a is nearly the same in both the cases of growth and starvation.

Literatures, cited.

1. T. Higurashi & M. Tauti: On the relation between temperature and the rate of development of fish-eggs. (Jour. Imp. Fish. Inst. Vol. XXI, No. 1, 1925).
2. S. Ueda: On the cold-storage of the living fronds of "Asakusanori." (Jour. Imp. Fish. Inst. Vol. XXIII, No. 1, 1927).
3. J. Hori: On the relation between the temperature and the vitality of the oyster preserved in the air. (Jour. Imp. Fish. Inst. Vol. XXIII, No. 5, 1928).
4. M. Kawajiri: On the preservation of the egg and sperm of *Oncorhynchus masou*. (Jour. Imp. Fish. Inst. Vol. XXIII, No. 2, 1927).
5. M. Kawajiri: On the relation between the temperature and the vitality of *spirogyra sp.* (Jour. Imp. Fish. Inst. Vol. XXIII, No. 2, 1927).

Aug., 1928.

Kizaki Fish-cultural Experiment Station,
Imp. Fish. Inst.

ON THE STUDIES OF THE POPULATION-DENSITY OF CULTURED FISHES I.

ON THE INFLUENCE OF POPULATION-DENSITY OF FISHES UPON THE SURVIVAL-RATE AND THE RATE OF GROWTH[1] (I).

By

Minoru Kawajiri.

R. Pearl and S. Parker[2] investigated the influence of the number on the rate of reproduction and the mean duration of life of *Drosophila* (fruit flies)

(1) Recentry A. Willer and E. Schnigenberg (Zeitschrift für Fischerei und deren Hilfswissenschaften. Band XXV, Heft 2, 1927) reported on the influence of population-density on the death-rate and the rate of growth of brook-trout.

(2) J. Lotka:—Elements of Physical Biology, 1925.

cultured in a bottle, and found that the rate of reproduction decreases as the population-density increases, whereas the duration of life does not gradually diminish as the density increases, but has a maximum value at a certain density.

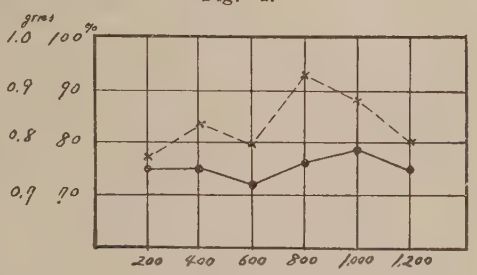
The mean duration of life depends upon the death-rate, and the rate of reproduction depends upon the number of eggs per female, the hatch-rate and the death-rate.

Thus we know that the population-density has a powerful effect upon the number of eggs per female, the hatch-rate and the death-rate.

The fishes used in the present study were young fry of rainbow trout. Their mean length was 26 mm. and their mean weight was 0.34 grams. Several numbers of the fry were cultured in 6 boxes ($1.58^m \times 0.33^m \times 0.24^m$) which were put in a shallow pond, over the water level of which the boxes stand and supplied with running water at 10～13° C. The quantity of the water supplied was 1.2 liters per minute per hundred fry, and the weight of dry matter supplied as the ration was 1.7 grams per day per hundred fry. The food matter was a mixture of fresh-meal, rice-bran and a few drops of cod-liver oil.

After the culture of 50 days from 8th Aug. to 26th Sep. 1927, the result was obtained as shown in Table I. Fig. 1 shows the influence of the number of fry in a box upon the survival-rate after 50 days and also upon the average weight.

Fig. 1.



○ ....Survival-rate.
× ....Body weight.

Table I. The result of 50 days experiment.

No.	Number of fishes used	Total weight of fishes used (N_0W_0)grs.	Number of catched fishes	Total weight of catched fishes (N_1W_1)grs.	Mean wight of catched fishes grs.	The survival-rate %	Total number of diminuted fishes	Total number of dead fishes
1	200	68	149	114	0.77	74.5	51	51
2	400	136	300	251	0.84	75.0	100	100
3	600	204	433	348	0.80	72.2	167	136
4	800	272	611	570	0.93	76.4	191	150
5	1,000	340	787	689	0.88	78.7	213	196
6	1,200	408	905	723	0.80	75.0	295	205

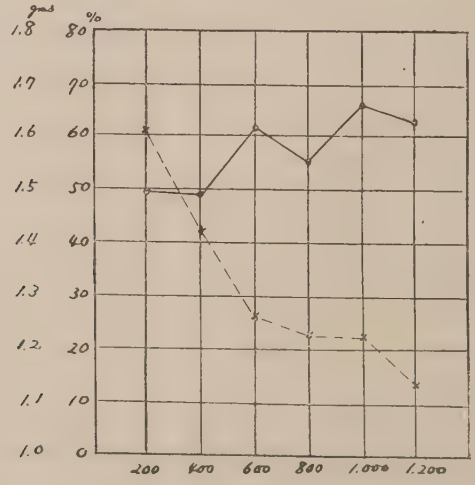
From Table I and Fig. 1 we see that the influence of the population-density was not remarkable within the period of 50 days.

On 11th Nov., after 96 days from the beginning, the result was obtained as shown in Table II and Fig. 2.

Table II. The result of 96 days experiment.

No.	Number of fishes used	Total weight of fishes used (N_0W_0)grs.	Number of catched fishes	Total weight of catched fishes (N_2W_2)grs.	Mean weight of catched fishes gms.	The survival-rate %	Total number of diminuted fishes	Total number of dead fishes
1	200	68	89	143	1.61	49.5	60	55
2	400	136	194	277	1.42	48.5	106	78
3	600	204	371	468	1.26	61.8	62	35
4	800	272	445	547	1.23	55.6	166	118
5	1,000	340	659	823	1.25	65.9	128	78
6	1,200	408	764	863	1.13	63.1	141	51

Fig. 2.



•....Sarvival-rate. ×....Body weight.

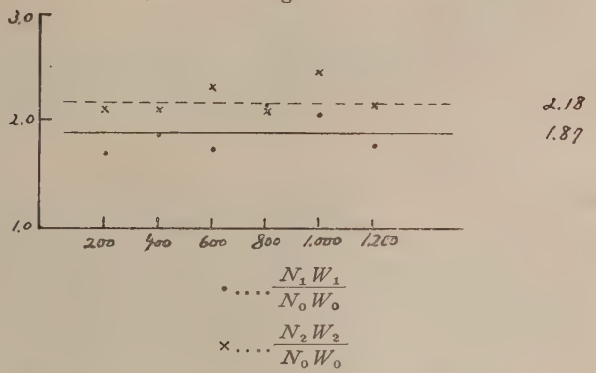
From Table II and Fig. 2 we see that after the culture of 96 days the survival-rate increases and the rate of growth decreases as the population-density increases.

Table III and Fig. 3 show the rate of increase of total weight of fishes in each box after 50 days-culture and the same after 96 days-culture which are calculated from Tables I and II.

Table III. The rate of increase of total weight of fishes.

No.	$\frac{N_1 W_1}{N_0 W_0}$	$\frac{N_2 W_2}{N_0 W_0}$
1	1.68	2.10
2	1.85	2.04
3	1.71	2.30
4	2.09	2.01
5	2.03	2.42
6	1.77	2.12
Mean	1.87	2.18

Fig. 3.



From Fig. 3 we may say that the rate of increase of total weight of fry in a box is not affected upon by population-density of fishes.

Before closing the paper I wish to express my sincere thanks to Dr. M. Tauti for his helpful advices.

Summary.

200～1,200 young fry of rainbow trout were cultured in several box of same size ($1.58^m \times 0.33^m \times 0.24^m$), being supplied with running water (11～13° C) and ration in proportion to the number of fry in each box. After 96 days-culture, we got the following results.

1. The survival-rate increases as the number of fry in a box increases.
2. The rate of growth decreases as the number of fishes in a box increases.
3. The rate of increase of total weight of fishes in a box is not affected upon by the number of fry in a box.

May, 1928.

Kizaki Fish-cultural Experiment Station,
Imp. Fish. Inst.

ON THE PREPARATION OF "ASAKUSANORI" FROM THE COLD STORAGE MATERIAL.

By S. Ueda.

As a preliminary study of the cold storage of the raw material of *Porphyra* I made an experiment to find out how long it lives in a good condition when kept frozen, and I found that it continues its living condition however long it is kept in that state. Thereupon, last winter, at Dr. Okamura's suggestion I tried to prepare merchandise of *Porphyra* that is "Asakusanori,"* from the material kept in cold storage, but the result proved to be a failure. This failure, I think, should be ascribed to the mixing of weak and unhealthy fronds in the raw material and also those dead during the freezing. The merchandise thus prepared was far inferior to such of high quality as sold in the market. So had we only selected the material which are in a good living condition at the outstart and prepared them, certainly we could have got a good merchandise. In ordinary material from which the merchandise is prepared by fishermen there may be mixed many weak and unhealthy ones, but as they are soon chopped and manufactured and dried in the sun, they do not become dead to spoil the quality of the merchandise.

ON THE PREPARATION OF "ASAKUSANORI" BY VACUUM DRYING.

By S. Ueda And K. Miyosi.

In preparing "Asakusanori,"* sun-heat drying is usually resorted to. But on a rainy or cloudy day when it is impossible to carry it out, fishermen make it a rule to apply stove heating instead. The present authors hit on vacuum drying which dispenses with a large ground allotted for sun-heat drying and is much better than drying by stove heating. This method has also advantage over the others in drying up the material in a shorter period without, however, raising temperature which would spoil quality of the merchandise. Under 40° C, it was found, the shorter a period for drying the material, the better the quality we could expect of it. It took about 3 hours to dry up the raw material under a pressure 15 m.m. and at a temperature 30° C. The final preparation thus obtained was better in quality than those dried in the sun.

* A commercial preparation of *Porphyra* in the form of thin paper.

ON THE INFLUENCE OF THE VARIATION OF TEMPERATURE OF WATER UPON THE HATCH-RATE AND THE HATCHING-DAYS* OF FISH EGGS.

By

Dr. M. Tauti.

§ 1. Previously, the author[1] has made a study on the relation between the temperature of water and hatching-days of fish eggs. It was found that within certain limits of temperature of water, this relation is given by the following equation (a):

$$\tau = Te^{-\alpha(\theta-\Theta)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (a)$$

where θ and θ are any two temperatures at which the development can normally take place for the many of given eggs, τ and T are the hatching-days corresponding to the temperature θ and θ respectively and α is a characteristic constant for given eggs.

Divide the whole development from fertilization to hatching of given eggs into n portions. Let the number of days required for the developments of the 1st, 2nd...., nth portion be T', T'', $\ldots, T^{(n)}$ respectively when the temperature of water is kept at θ. Then we have

$$T = \Sigma T^{(\kappa)}$$

Next, let the number of days reguired for the development of the 1st portion be τ' when the temperature of water is θ', and the number of days required for the development of the 2nd portion be τ'' when the temperature of water is θ'' and so on. Then we have

$$\tau^{(\kappa)} = T^{(\kappa)} e^{-\alpha(\theta^{(\kappa)}-\Theta)} \qquad [k=1, 2, \ldots, n].$$

Thus in this case, the hatching-days τ_μ is

$$\tau_\mu = \Sigma\tau^{(\kappa)} = \Sigma T^{(\kappa)} e^{-\alpha(\theta^{(\kappa)}-\Theta)}$$

The average temperature of water, θ_m, and the variation of mean square, μ, are

$$\theta_m = \frac{\Sigma \tau^{(\kappa)} \theta^{(\kappa)}}{\Sigma \tau^{(\kappa)}} \quad \text{and} \quad \mu^2 = \frac{\Sigma \tau^{(\kappa)} (\theta^{(\kappa)} - \theta_m)^2}{\Sigma \tau^{(\kappa)}}.$$

If the temperature of water is kept at θ_m throughout the whole development the hatching-days, τ_0, is given by

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* Hatching-days means the number of days needed for the development from fertilization to hatching of eggs.

(1) J. Imper. Fish. Inst. XXI, No. 1. (1925).

$$\tau_0 = Te^{-\alpha(\theta_m-\Theta)} = \Sigma T^{(\kappa)} e^{-\alpha(\theta_m-\Theta)}.$$

Thus
$$\tau_0 - \tau_\mu = \Sigma T^{(\kappa)}[e^{-\alpha(\theta_m-\Theta)} - e^{-\alpha(\theta^{(\kappa)}-\Theta)}]$$
$$= \Sigma T^{(\kappa)} e^{-\alpha(\theta^{(\kappa)}-\Theta)}[e^{\alpha(\theta^{(\kappa)}-\theta_m)} - 1]$$
$$= \Sigma T^{(\kappa)}[\alpha(\theta^{(\kappa)}-\theta_m) + \frac{\alpha^2}{2}(\theta^{(\kappa)}-\theta_m)^2 + \ldots.]$$

Then we have
$$\tau_0 - \tau_\mu = \frac{\alpha^2}{2} \cdot \mu^2 \cdot \tau_\mu$$

or
$$\frac{\tau_0}{\tau_\mu} - 1 = \frac{\alpha^2}{2} \cdot \mu^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (A)$$

This equation (A) gives the relation between the hatching-days, τ_0, in the case where the water is kept at a constant temperature and the hatching-days, τ_μ, when the temperature of water varies in such a way as the mean value coincides with the value of that constant temperature and the variation of mean square is μ.

§ 2. In another paper[2] the author has investigated the relation between the temperature of water and the hatch-rate of fish eggs and has come to the conclusion that within certain limits of the temperature of water, the relation is expressed in the following equation

$$\frac{N}{N_0} = \left(\frac{N}{N_0}\right)_{\bar{\theta}} e^{-c(\theta-\bar{\theta})^2} \quad \ldots\ldots \ldots\ldots\ldots\ldots\ldots (b),$$

where $\bar{\theta}$ is the optimum temperature for the development of given eggs, while the hatch-rate is $\left(\frac{N}{N_0}\right)_{\bar{\theta}}$ when the temperature of water is kept at $\bar{\theta}$, and hatch-rate is $\frac{N}{N_0}$ when the temperature of water is kept at θ. c is a characteristic constant for given eggs.

Now, divide the whole development from fertilization to hatching into n portions in such a way as the number of days required for the developments of the 1st, 2nd, ..., nth portion at $\bar{\theta}$ are T', T'', ..., $T^{(n)}$ resp. And consider that, among N_0 fertilized eggs $N^{(\kappa)}$ eggs live out the first κ portions.

Next suppose that the development of the 1st portion takes τ' days, at a temperature, θ', and the development of the 2nd portion takes τ'' days at θ'' and so on. And consider that among N_0 fertilized eggs $N^{(\kappa)}$ eggs live out the first κ portions.

(2) J. Imper. Fish. Inst. XXIII, No. 2. (1927).

Then, $\tau^{(\kappa)} = T^{(\kappa)} e^{-\alpha(\theta^{(\kappa)}-\bar{\theta})} \qquad [\kappa=1, 2, \ldots, n]$

Let the value of the constant, c, for the 1st, 2nd, ..., nth portion be c', c'',...., $c^{(n)}$ resp.

Then,
$$\frac{N'}{N_0} = \frac{\bar{N}'}{N_0} e^{-c'(\theta'-\bar{\theta})^2},$$
$$\frac{N''}{N'} = \frac{\bar{N}''}{\bar{N}'} e^{-c''(\theta''-\bar{\theta})^2},$$
$$\cdots\cdots\cdots\cdots\cdots\cdots$$
$$\frac{N^{(n)}}{N^{(n-1)}} = \frac{\bar{N}^{(n)}}{\bar{N}^{(n-1)}} e^{-c^{(n)}(\theta^{(n)}-\bar{\theta})^2}.$$

Hence $$\frac{N^{(n)}}{N_0} = \frac{\bar{N}^{(n)}}{N_0} e^{-\Sigma c^{(\kappa)}(\theta^{(\kappa)}-\bar{\theta})^2}.$$

When the temperature of water is kept constant, θ, throughout the whole development, we have

$$\theta' = \theta'' = \ldots = \theta^{(n)} = \theta$$

Thus $$\frac{N^{(n)}}{N_0} = \frac{\bar{N}^{(n)}}{N_0} e^{-(\theta-\bar{\theta})^2 \Sigma c^{(\kappa)}}$$

But $$\frac{N^{(n)}}{N_0} = \frac{\bar{N}^{(n)}}{N_0} e^{-c(\theta-\bar{\theta})^2}$$

Hence $\Sigma c^{(\kappa)} = c.$

Here, assume $$c^{(\kappa)} = \frac{T^{(\kappa)}}{\Sigma T^{(\kappa)}} . c \qquad [\kappa=1, 2, \ldots, n]$$

Then $$\frac{N^{(n)}}{N_0} = \frac{\bar{N}^{(n)}}{N_0} e^{-c \cdot \frac{\Sigma T^{(\kappa)}(\theta^{(\kappa)}-\bar{\theta})^2}{\Sigma T^{(\kappa)}}}$$

Since $$\frac{\Sigma T^{(\kappa)}(\theta^{(\kappa)}-\bar{\theta})^2}{\Sigma T^{(\kappa)}} = (\theta_m-\bar{\theta})^2 + [1+2\alpha(\theta_m-\bar{\theta})]\mu^2,$$

where $$\theta_m = \frac{\Sigma \tau^{(\kappa)}\theta^{(\kappa)}}{\Sigma \tau^{(\kappa)}} \text{ and } \mu^2 = \frac{\Sigma \tau^{(\kappa)}(\theta^{(\kappa)}-\theta_m)^2}{\Sigma T^{(\kappa)}}.$$

Then $$\frac{N^{(n)}}{N_0} = \frac{\bar{N}^{(n)}}{N_0} e^{-c(\theta_m-\bar{\theta})^2} e^{-c[1+2\alpha(\theta_m-\bar{\theta})]\mu^2}$$

Denote the hatch-rate by $\left(\frac{N}{N_0}\right)_0$ when the temperature of water is kept constant θ_m, and by $\left(\frac{N}{N_0}\right)_\mu$ when the temperature of water varies, in such a way as the mean value is θ_m and the variation of mean square is μ,

then $$\left(\frac{N}{N_0}\right)_\mu=\left(\frac{N}{N_0}\right)_0 e^{-c(1+2\lambda(\theta_m-\bar{\theta})]\mu^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (B)$$

because $$\left(\frac{N}{N_0}\right)_0=\frac{\bar{N}^{(n)}}{N_0}e^{-c(\theta_m-\bar{\theta})^2} \text{ and } \left(\frac{N}{N_0}\right)_\mu=\frac{N^{(n)}}{N_0}.$$

This equation (B) represents the relation between the variation of mean square and the hatch-rate.

§ 3. M. Kawajiri[3] made a study on the effect of the mean variation of temperature of water upon the hatch-rate and upon the hatching-days of eggs of *Leuciscus hakuensis*, Günther and *Carassius auratus*, Linné.

In this case

$$\tau'=\tau''=\ldots\ldots=\tau^{(n)}, \qquad \theta'=\theta'''=\ldots\ldots=\bar{\theta}+\varepsilon, \qquad \theta''=\theta''''=\ldots\ldots=\bar{\theta}-\varepsilon$$

Hence $$\theta_m=\bar{\theta}, \qquad \mu=\varepsilon$$

Demote the mean variation of the temperature by M,

$$M=\frac{\Sigma\tau^{(\kappa)}|\theta^{(\kappa)}-\theta_m|}{\Sigma\tau^{(\kappa)}}=\varepsilon$$

Hence, $$\mu=M$$

Therefore, the equations (A) and (B) become the following (A') and (B') respectively.

$$\frac{\tau_0}{\tau_M}-1=\frac{a^2}{2}M^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (A')$$

$$\left(\frac{N}{N_0}\right)_M=\left(\frac{N}{N_0}\right)_0 e^{-cM^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (B')$$

(i) Table I gives the relation between the mean variation of temperature of water and the hatch-rate as well as that between the mean variation and the hatching-days of eggs of *Carassius auratus*, Linné.

Table II and Fig. 1 show the values of $\log\left[\left(\frac{N}{N_0}\right)_M/\left(\frac{N}{N_0}\right)_0\right]$, $\frac{\tau_0}{\tau_M}-1$ and M^2 calculated from the data given in Table I.

Table I.

θ_m °C	13.8	13.9	13.6	13.3
M°C	0.5	1.9	2.5	3.8
$\left(\frac{N}{N_0}\right)_M$	0.72	0.70	0.71	0.69
$\left(\frac{N}{N_0}\right)_0$	0.77	0.77	0.77	0.77
τ_M day	10.8	11.4	11.0	11.0
τ_0 day	11.5	11.5	12.0	12.7

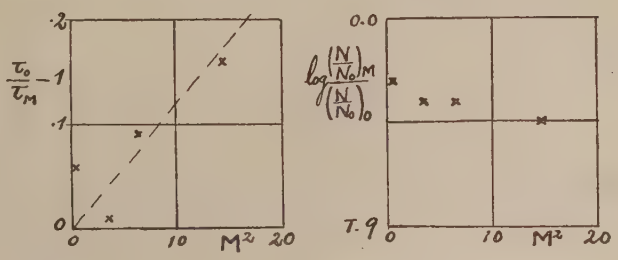
Table II.

M^2	0.3	3.6	6.3	14.5
$\log\left[\left(\frac{N}{N_0}\right)_M/\left(\frac{N}{N_0}\right)_0\right]$	$\bar{1}.97$	$\bar{1}.96$	$\bar{1}.96$	$\bar{1}.95$
$\frac{\tau_0}{\tau_M}-1$	0.06	0.01	0.09	0.16

(3) J. Imper. Fish. Inst. XXIII, No. 3. (1927).

Fig. 1 is not sufficient to verify the equation (B'), but it shows that the equation (A') holds good. And from the broken line in this figure we have

Fig. 1



$$\therefore \frac{a^2}{2}=0.0120, \qquad a=0.154, \qquad Q_{10}=4.7$$

From the results of the experiments for control, using the formula (a), Kawajiri obtained

$$Q_{10}=4.6$$

(ii) Table III gives the relation between the mean variation of temperature of water and hatch-rate as well as that between the mean variation and the hatching-days of eggs of *Leuciscus hakuensis*, Günther.

Table IV and Fig. 2 show the values of $\log\left[\left(\frac{N}{N_0}\right)_M\Big/\left(\frac{N}{N_0}\right)_0\right]$, $\frac{\tau_0}{\tau_M}-1$ and M^2 calculated from the data given in Table III.

Table III.

θ_m °C	14.9	14.8	14.5	14.2	13.5
M °C	0.7	2.1	3.5	4.8	6.5
$\left(\frac{N}{N_0}\right)_M$	0.75	0.64	0.49	0.34	0.08
$\left(\frac{N}{N_0}\right)_0$	0.82	0.83	0.86	0.88	0.89
τ_M day	4.6	4.6	5.1	5.1	3.8
τ_0 ,,	5.0	5.1	5.3	5.5	6.1

Table IV.

M^2	0.5	4.4	12.2	23.0	42.2
$\log\left[\left(\frac{N}{N_0}\right)_M\Big/\left(\frac{N}{N_0}\right)_0\right]$	$\bar{1}.97$	$\bar{1}.89$	$\bar{1}.76$	$\bar{1}.59$	$\bar{2}.96$
$\frac{\tau_0}{\tau_M}-1$	0.09	0.11	0.04	0.08	0.60

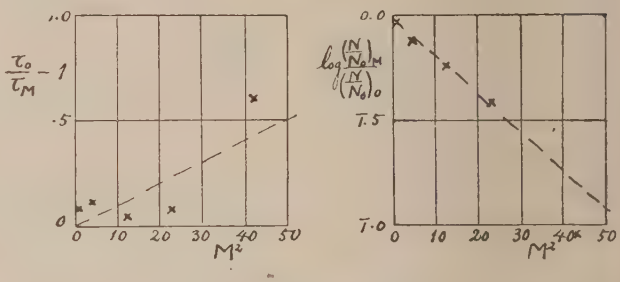
Fig. 4 shows that the equations (A') and (B') nearly hold good. And from the broken lines in this figure we obtain

$c \log e = 0.0180$, $c = 0.041$

$\frac{a^2}{2} = 0.0100$, $a = 0.141$,

$Q_{10} = 4.2$

Fig. 4



From the results of Nakai's experiment[4] on the effect of the temperature of water upon the hatch-rate of the eggs of *Leuciscus hakuensis*, Günther, using the formula (b) we obtained $c = 0.039$. From the results of Kawajiri's experiment[3] for control, using the formula (b) we obtain $c = 0.030$ and $Q_{10} = 3.9$.

Seeing that the values of the constants calculated by the application of the equations (A') and (B') coincide with the values of the constants calculated from the results of experiments for control using the formulae (a) and (b) we can say that the theories above stated are proved to be right.

In short, when the variation of temperature of water is not very rapid, the influence of the variation of temperature of water upon the hatching of fish eggs is represented by the equations (A) and (B) above obtained.

Summary.

The influence of the variation of temperature of water upon the hatching-days and the hatch-rate of fish-eggs is represented by the following equations

$$\frac{\tau_0}{\tau_\mu} - 1 = \frac{a^2}{2}\mu^2, \quad \text{and} \quad \left(\frac{N}{N_0}\right)_\mu = \left(\frac{N}{N_0}\right)_0 e^{-c[1+2(\theta_m-\bar{\theta})]\mu^2},$$

where τ_μ and $\left(\frac{N}{N_0}\right)_\mu$ denote the hatching-days and the hatch-rate when the temperature of water varies, in such a way as the mean value is θ_m and the variation of mean square is μ, and τ_0 and $\left(\frac{N}{N_0}\right)_0$ those when the temperature is kept at θ_m throughout the whole development, and $\bar{\theta}$ is the optimum temperature for hatching. a and c are characteristic constants for given eggs.

April, 1928. Physical laboratory, Imp. Fisher. Institute, Tôkyô.

(4) J. Imper. Fish. Inst. XXII, No. 4. (1927).

ON THE ACTION OF TOXIC SUBSTANCES.

By

Dr. M. Tauti and H. Yasuda.

Take a number of individuals of a certain age or of a certain stage of a given species and take a property that may easily be measured for each individual—mainly a morphological property capable of direct measurement, and plot a frequency curve. As already ascertained by the studies of many authors, this curve is a probability curve.

Previously one of the writers, Tauti[1] pointed out that the same relation holds for a property which is not directly measurable, *i. e.*, for the optimum temperature and salinity for the development of fish-eggs.

With regard to the action of toxic substances, we may suppose that the same relation holds. Namely, a concentration, X, of a solution of toxic substance to cause death of a given living thing in a definite interval of time, that is to say, a lethal concentration corresponding to a definite time, may not be the same for all individuals of the same species.

When by y, we express the ratio of the number of individuals meeting with death at a concentration, X, to the total number of individuals, and by M express the mean value of X for the total individuals, the relation between y and X can be represented by the next formula (1)

$$y=\frac{1}{\sqrt{2\pi}\,.\,\sigma}\,e^{-\frac{1}{2}\left(\frac{X-M}{\sigma}\right)^2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where σ denotes the standard variation of the lethal concentration and it depends upon the species of the living things, the age, the sort of toxic substance used and so on.

Then consider a number of individuals kept in the solution of a toxic substance of the concentration X. In this case, all the individuals for which the lethal concentration in a given definite interval of time is smaller than X will be brought to death within that interval.

Hence, the ratio, R, of the number of individuals brought to death within that interval to the total number of individuals, that is to say, the death-rate will be given by the expression (2).

(1) M. Tauti: On the influence of temperature and salinity upon the rate of development of fish-eggs. (J. Imper. Fish. Inst., XXIII, 2, 61-67, 1928).

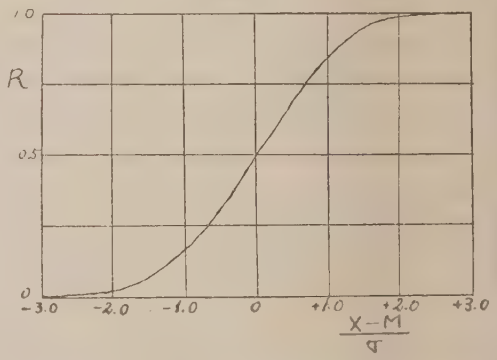
$$R=0.5+\frac{1}{\sqrt{2\pi}}\int_0^{\frac{X-M}{\sigma}} e^{-\frac{1}{2}x^2}\,dx \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

The relation of the death-rate, R, to the value of $\frac{X-M}{\sigma}$ calculated from the above equation (2) is shown in Table I and Fig. 1.

Table I.

$\frac{X-M}{\sigma}$	−3.0	−2.5	−2.0	−1.5	−1.0	−0.5	0.0	+0.5	+1.0	+1.5	+2.0	+2.5	+3.0
R	.00	.01	.02	.07	.16	.31	.50	.69	.84	.93	.98	.99	1.00

Fig. 1.



Nozaki[1] made a study on the toxic action of CS_2 and $C\,Cl_4$ on the eggs of a kind of fly. The eggs were put in a small watch-glass, placed in a glass bottle and then the bottle was tightly covered up as soon as a few drops of CS_2 or $C\,Cl_4$ were dropped into it. Then after a few minutes the watch-glass was taken out from the bottle. After the hatching of the eggs, he counted the number of grubs and determined the death-rate. The result of his experiment is summarized in Table II and Fig. 2.

Table II.

Toxic substance: CS_2

Time interval of action.	Number of drops				
	0	1	2	3	4
30 min.	4.5	24.5	50.0	93.9	99.1
60		29.8	78.6	99.2	100.0
90		80.0	96.2	100.0	100.0
120		73.5	100.0	100.0	100.0

Toxic substance: CCl_4

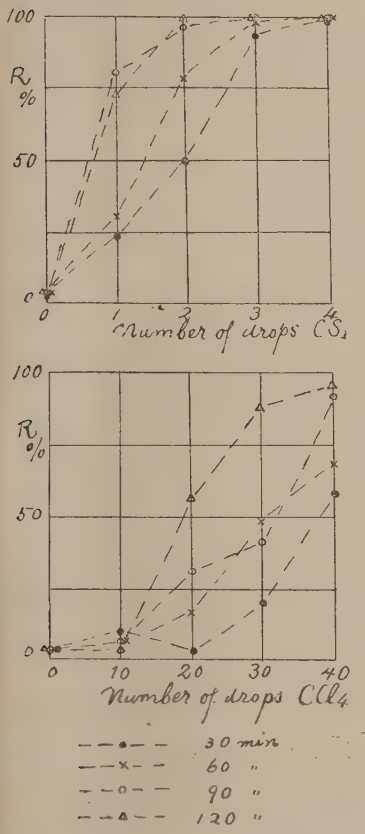
Time interval of action.	Number of drops				
	0	10	20	30	40
30 min.	4.5	10.0	3.3	20.0	57.8
60		6 6	16.0	48.5	68.8
90		6.6	30.5	40.1	91.6
120		4.4	56.1	88.3	95.6

(1 Nakatarô Nozaki made this experiment under the guidance of Tauti, one of the writers.

Table III.

Concentration of original solution in gr/litre	temperature in °C	Action-time in hour	Ratio of concentration used to that of original solution Death-rate									
(1) Experimental animal: larva of *Culex sp.* Toxic substance: lime.												
0.3	room temperature	18	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85
			.65	.80	.80	.90	.90	.90	.95	1.00	1.00	.95
		22	.37	.44	.51	.58	.65	.72	.79	.86	.93	1.00
			.36	.70	.95	.95	.95	.90	.95	.95	.95	.85
			.15	.20	.25	.30	.35	.40	.45	.50	.55	.60
		20	.10	.10	.00	.10	.40	.40	.70	.80	1.00	.70
		26	.10	.10	.00	.10	.40	.40	.70	.80	1.00	.80
0.5	,,		.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
		3	.00	.00	.00	.00	.00	.00	.15	.25	.25	.55	.55
		20	.00	.00	.10	.53	.60	.80	.75	.90	.90	.85	.95
		24	.00	.05	.10	.80	.75	.90	.95	.95	.90	.95	1.00
1.0	,,		.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	
		6	.00	.05	.35	.70	.85	.75	.80	.75	.90	.75	
		9	.00	.10	.65	.85	1.00	.90	.90	.85	1.00	.95	
			.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	
		3	.00	.00	.20	.10	.35	.55	.55	.70	.60	.75	
		4.6	.00	.00	.20	.35	.40	.45	.90	.80	.90	.90	
		6.6	.00	.20	.30	.70	.80	.85	1.00	.95	.90	.95	
			.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	
		3	.00	.00	.15	.30	.20	.50	.50	.40	.50	.60	
		5	.00	.05	.20	.70	.50	.85	.85	.85	.95	.85	
		7	.00	.05	.50	.80	.55	.90	.80	.95	1.00	.95	
2.0	,,		.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
		2	.00	.05	.10	.10	.20	.15	.35	.35	.35	.45	.45
		4	.00	.10	.45	.65	.65	.70	.80	1.00	.70	1.00	.95
(2) Experimental animal: larva of *Culex sp.* Toxic subtance: bleaching powder.												
			.55	.60	.65	.70	.75	.80	.85	.90	.95	1.00	
0.2	room temperature	19	.50	.50	.60	.90	.85	.75	.85	.90	.80	1.00	
0.4	,,		.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00	
		16	.20	.70	.90	.90	1.00	1.00	1.00	1.00	1.00	1.00	
			.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00	
		8.5	.10	.20	.40	.60	.40	.50	.90	.90	.90	1.00	
			.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	
		18	.25	.25	.35	.50	.80	.80	.90	.95	1.00	1.00	
			.05	.15	.25	.35	.45	.55	.65	.75	.85	.95	
		7.5	.00	.30	.40	.50	.80	.80	.90	.90	1.00	.90	
		22	.60	.80	1.00	.90	1.00	1.00	1.00	1.00	1.00	1.00	
0.8	,,		.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	
		4	.00	.00	.00	.00	.05	.05	.10	.30	.25	.55	
		7	.00	.05	.10	.40	.35	.55	.65	.85	.80	.95	
		18	.00	.35	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
			.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00	
		6	.00	.00	.10	.40	.40	.50	.80	.70	.70	.90	
		17	.90	.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
1.0	,,		.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
		4	.00	.00	.00	.10	.10	.10	.30	.20	.35	.40	.75
		6	.00	.05	.10	.30	.40	.50	.70	.55	.60	.75	.95
1.5	,,		.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
		4	.00	.05	.10	.05	.30	.40	.55	.45	.55	.75	.75
		5	.00	05	.25	.35	.45	.75	.70	.65	.90	.90	.85
		7	.00	.15	.35	.60	.80	.90	.90	.75	.95	.95	.90
2.0	,,		.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	10.0
		3	.00	.00	.05	.10	.25	.20	.35	.25	.50	.55	.45
		4	.00	.05	.15	.30	.50	.45	.50	.60	.75	.65	.55
		6	.00	.20	.35	.50	.70	.80	.80	.90	.85	.95	.85
		8	.00	.35	.45	.85	.90	.95	1.00	.95	.95	1.00	1.00
(3) Experimental animal: larva of *Chironomus sp.* Toxic substance: bleaching powder.												
			.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	
0.4	38	1.0	.00	.00	.30	.40	.50	.80	.70	.70	1.00	.90	
		1.5	.00	.10	.50	.80	1.00	.80	1.00	.90	.80	.90	
	32		.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	
		3.0	.00	.00	.30	.55	.20	.70	.70	.80	1.00	.70	
	27		.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	
		5.0	.00	.20	.20	.50	.70	.50	.70	.80	.90	.70	
		5.5	.00	.20	.60	1.00	.90	1.00	1.00	1.00	1.00	1.00	
	20		.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	
		8.5	.00	.00	.10	.30	.40	.40	.70	.80	.80	.90	
		11.5	.00	.10	.20	.80	1.00	.90	1.00	1.00	1.00	1.00	
0.04	32		.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	
		6.0	.00	.00	.00	.00	.00	.00	.10	.30	.40	.70	
		9.0	.00	.00	.00	.00	.30	.20	.70	.90	.70	1.00	
		21.0	.00	.10	.20	.50	.60	.80	1.00	1.00	1.00	1.00	
	27		.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	
		17.5	.00	.00	.00	.00	.00	.00	.20	.40	.80	.70	
		20.0	.00	.00	.00	.00	.00	.10	.70	.80	1.00	.90	
		35.0	.00	.00	.00	.00	.60	.70	1.00	1.00	1.00	1.00	
	20		.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	
		35.5	.00	.00	.00	.00	.00	.20	.60	.70	.80	.80	

Fig. 2.



We may, therefore, consider that the curves in Fig. 2 coincide with the curve in Fig. 1. Namely, the relation between the death-rate and the concentration of the toxic substance may, on the whole, be expressed by the curve in Fig. 1, and therefore by the formula (2).

To verify the formula (2) more precisely, we made an experiment of the toxic action of lime and bleaching powder on larvae of *Culex sp.* and *Chironomus sp.*

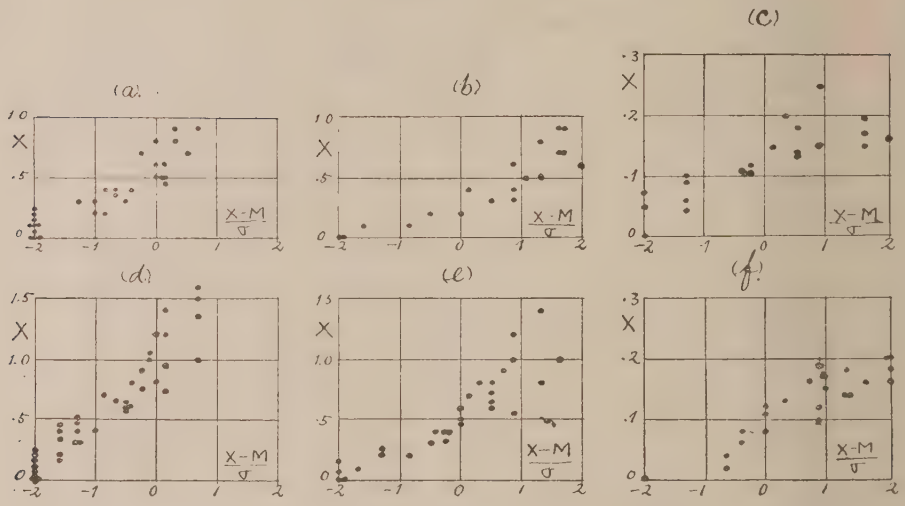
We prepared original solution which is an aqueous solution of the toxic substance of a proper concentration, and we put the larvae in several solutions which were obtained by mixing the original solution and water in various ratio according to circumstances, and then measured death-rate after a definite interval of time or for a definite action-time.

The results are tabulated in Table III.

To verify whether the relation between the death-rate and the concentration of the solution of toxic substances can be expressed by the formula (2) or not, we have to calculate from the formula (2), the value of $\frac{X-M}{\sigma}$ which gives the observed value of the death-rate in a given concentration, X, taking the value of $\frac{X-M}{\sigma}$ thus calculated as abscissa, and the given value of the concentration, X, as ordinate, and thus to see whether the relation between $\frac{X-M}{\sigma}$ and X be represented by a straight line or not.

In the cases where the action-times are 3.0, 6.6~7.0 and 20~22 in Table III (1) and where the action-times are 4.0, 6.0 and 18~19 in Table III (2), the relations between X and $\frac{X-M}{\sigma}$, obtained by the method just stated above, are represented in Fig. 3 by graphs a, b, c, d, e and f respectively.

Fig. 3.



In Fig. 3 we know that the relation between X and $\frac{X-M}{\sigma}$ is approximately rectilinear when the value of $\frac{X-M}{\sigma}$ lies between -1.3 and $+1.3$ or the value of the death-rate lies between 0.1 and 0.9.

The value of the mean lethal concentration, M, is given as the value of X when $\frac{X-M}{\sigma}$ is equal to zero from the straight line representing the relation between X and $\frac{X-M}{\sigma}$, and σ is given as the difference of the value of X against the unit difference of the value of $\frac{X-M}{\sigma}$.

The values of M and σ, calculated by the method just referred to from the data in Table III, are given in Table IV.

Fig. 4, (1) graphically shows the relation between M and σ in Table IV (1) and (2). In this figure, we see that two relations of M and σ for lime and bleaching powder coincide well with each other. And we have $\sigma=\frac{M}{2}$ in the both cases.

Fig. 4, (2) shows the relation between M and σ in Table IV (3). In this figure, we find that the temperature does not influence the relation of M and σ. In this case also we have $\sigma=\frac{M}{2}$.

Fig. 4.

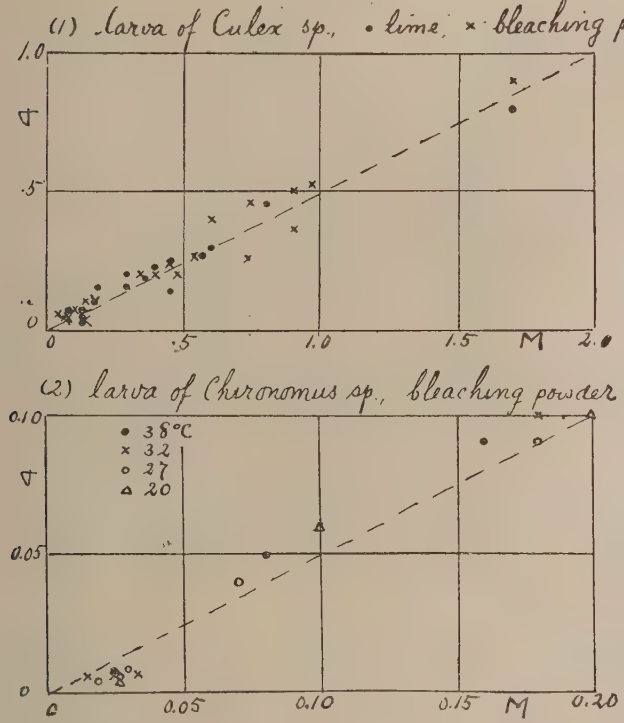


Table IV.

(1) Experimental animal: larva of *Culex sp.*
Toxic substance: lime
Temperature: room temperature.

Action-time in hours T	Mean lethal concentration in gr/litre M	Standard variation in gr/litre σ
18	.08	.08
22	.12	.08
20	.12	.05
26	.12	.04
3	.45	.13
20	.19	.15
24	.18	.10
6	.40	.22
9	.30	.16
3	.57	.28
4.6	.45	.25
6.6	.30	.20
3	.60	.30
5	.40	.20
7	.36	.19
2	1.7	.80
4	.80	.45

(2) Experimental animal: larva of *Culex sp.*
Toxic substance: bleaching powder
Temperature: room temperature.

Action-time in hours T	Mean lethal concentration in gr/litre M	Standard variation in gr/litre σ
19	.12	.04
16	.07	.06
8.5	.18	.10
18	.07	.05
7.5	.14	.10
22	.04	.06
4	.73	.26
7	.35	.20
18	.10	.08
6	.48	.20
4	.90	.37
6	.53	.27
4	.98	.52
5	.74	.45
7	.45	.24
3	1.7	.90
4	.90	.50
6	.60	.40
8	.40	.20

(3) Experimental animal: larva of *Chironomus sp.*
Toxic substance: bleaching powder

Action-time in hours T	Temperature °C θ	Mean lethal concentration in gr/litre M	Standard variation in gr/litre σ
1.0	38	.16	.09
1.5	〃	.08	.05
3.0	32	.18	.10
5.0	27	.18	.09
5.5	〃	.07	.04
8.5	20	.20	.10
11.5	〃	.10	.06
6.0	32	.033	.007
9.0	〃	.024	.006
21.0	〃	.014	.006
17.5	27	.030	.009
20.0	〃	.024	.006
35.0	〃	.018	.003
35.5	20	.026	.006

That is to say, the coefficient of variability, $\frac{\sigma}{M}$, depends only upon the species of living being, not upon the sort of toxic substances and the temperature.

The relation between the action-time, T, and the mean lethal concentration, M, and that between $\frac{1}{T}$ and M, and that between log T and log M are shown in Fig. 5 by graphs (a), (b) and (c) respectively.

The graphs (a) and (b) in Fig. 5 show that the relations between T and M as well as between $\frac{1}{T}$ and M seem to coincide with the result obtained by Powers[1], but not follow the Powers' theory when the concentration is very small.

From (c) in Fig. 5, we know that the relation between T and M obeys Ostward's formula (3)

$$\frac{1}{T}=kM^{p} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

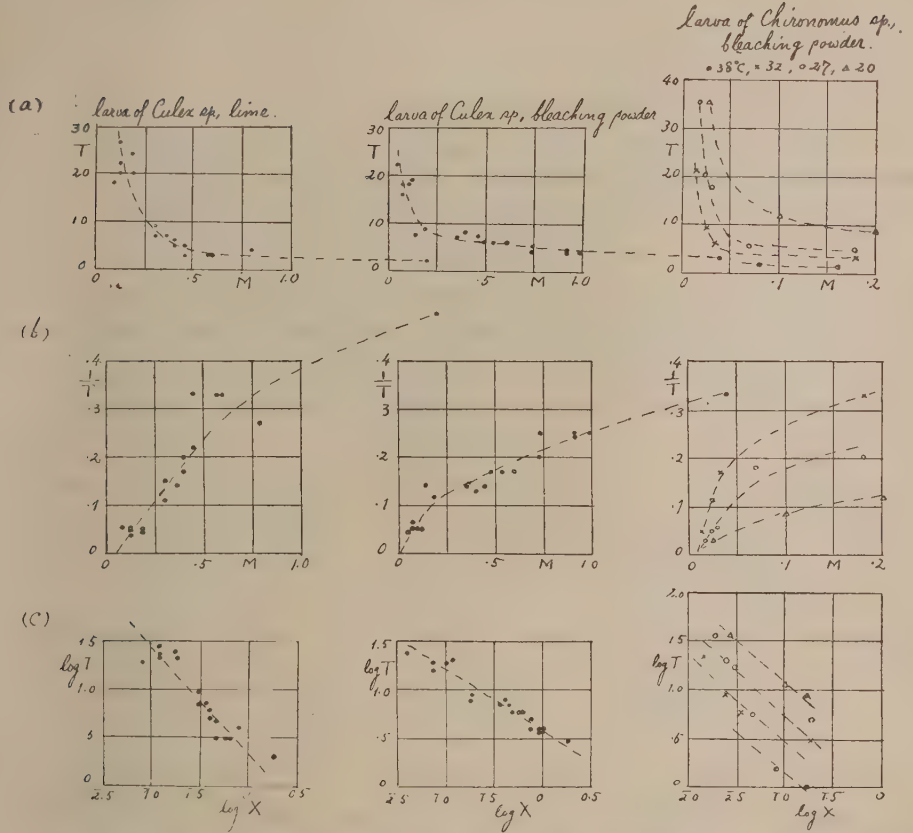
and in this case the values of k and p are given in Table V.

Table V.

larva of *Culex sp.*	lime		$k=0.5$	$p=1.12$
〃	bleaching powder		$k=0.27$	$p=0.63$
larva of *Chironomus sp.*	bleaching powder	$\theta=38°C$	$k=51.0$	$p=0.85$
		$\theta=32$	$k=22.0$	
		$\theta=27$	$k=12.8$	
		$\theta=20$	$k=6.2$	

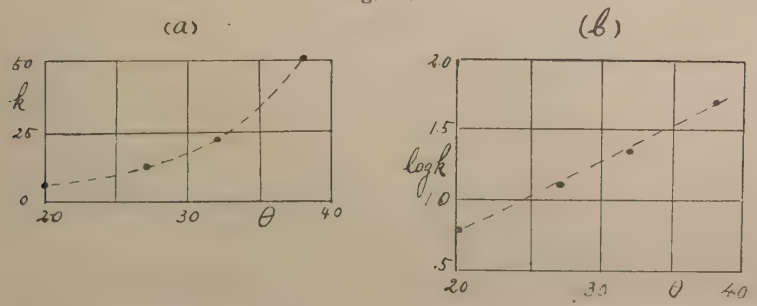
(1) Edwin B. Powers: The gold-fish as a test animal in the study of toxicity. (Illinois Biological Monographs, IV, 2, 1917).

Fig. 5.



In Fig. 6, the graph (a) represents the relation between the constant k and the temperature θ given in Table V, and the graph (b) shows the relation of log k and θ which are calculated from Table V. Evidently, k denotes the inverse of the survival-time T when the lethal concentration is one gram per litre.

Fig. 6.



Lethal process is due to coagulation of protoplasm colloid as a result of mixing the toxic substance (mainly the ion) and the colloid. And this reaction may be considered as a homogeneous reaction, because the change of quantity of the toxic substance can not be recognized in the course of the reaction. Hence the equation of Arrhenius holds for the speed of toxic action*, and as the temperature which has no destructive effect on life, ranges within only some ten-degrees, the relation is given approximately by the next fomula (4)

$$Te^{a\theta}=C \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where T is the survival-time at the temperature $\theta\,^{\circ}C$, and C is a constant depending upon the species of living things, sort of toxic substance and its concentration, and a is a constant depending only upon species of living thing.

And the temperature coefficient, Q_{10}, of the toxic action is given by

$$\log Q_{10}=10\,a\log e$$

Dernoscheck[1] calculated the value of Q_{10} of the toxic action of sea-water for *Daphinia* and obtained the next results.

Temperature °C	5–15	15–25	25–35	35–45
Q_{10}	2.3	1.8	2.0	2.5

Koizumi[2] obtained the value of Q_{10} of the toxic action of sea-water for *Chironomus virridicorris*, Van der Walp.

Temperature °C	10–15	15–20	20–25
Q_{10}	1.36	3.06	2.61

In Fig. 6, the graph (b) shows that the relation between T and θ satisfies the formula (4). Calculating the temperature coefficient, Q_{10}, from this figure, we get

$$Q_{10}=3.2$$

In conclusion, we should like to express our hearty thanks to Professors A. Terao and N. Nakai for their valuable advices.

Summary.

1. When the concentration of the solution of the toxic substance is X, the death-rate under the action of the toxicity for a definite interval of time is given

* K. E. Carpenter confirmed that for toxic action of soluble metallic salts which is not normal toxic type established by Powers but which is purely external in process, chemical in type, and mechanical in effect, the speed of the reaction varies in direct relation to the temperature consistently with van't Hoff's Rule. (British. J. Exp. Biol., 4 (4) 378-390, 1927).

(1) A. Dernoscheck, Pflüger's Arch. 143, 303-369 (1912).

(2) S. Koizumi, Dobutsugaku-zasshi (In Japanese) 40, 474, 131-152 (1928).

by the next formula

$$R=0.5+\int_0^{\frac{x-M}{\sigma}} e^{-\frac{1}{2}x^2}\,dx,$$

where M is the mean lethal concentration for that definite time and σ the standard variation.

2. The value of $\frac{\sigma}{M}$, coefficient of variability, depends only upon the species of the living things tested, but it does not depend upon the sort of the toxic substance and the temperature.

3. The temperature remaining the same, the relation between the mean lethal concentration, M, and the action-time, T, follows Ostward's formula.

4. The mean lethal concentration remaining the same, the relation between the temperature, θ, and the action-time, T, is represented by the next formula

$$Te^{\alpha\vartheta}=\text{Const.}$$

where α is a constant depending only upon the species of the living things tested.

That is to say, the relation between the temperature and the survival time follows this formula when the concentration of the toxic substance remains the same.

July, 1928. Physical laboratory, Imp. Fish. Institute, Tôkyô.

ON THE INFLUENCE OF THE TEMPERATURE UPON THE HATCHING OF EGGS OF *PLECOGLOSSUS ALTIVELIS* T. & S.

By

Nobutaka Nakai.

In 1924 Higurashi[1] stated that the eggs of *Plecoglossus altivelis* develop normally at temperatures 10°–19° C., the optimum being about 15° C. But his data were too meagre to determine the limit of the favourable temperature for the hatching of the eggs. Hereon, the lower limit was, in the next year, decided both by him and myself[2] to be about 10° C., and the higher one is now recorded in this paper.

The experimental method was the same as that of the previous experiments. The eggs used were taken at Futako, one of the spawning grounds in the Tama River near Tokyo, in three series of experiments in different periods of the spawning season. In the first and second experiments, the thermostat was, referring to the previous experiments, regulated to maintain temperatures about 20°–8° C., resulting in a failure to determine the higher limit; the range of the temperature was, therefore, changed to 23.8°—6.6° C. in the third experiment. The reason why the range of the temperature was extended lower is to test the limit of the favourable temperature may vary in accordance with the difference of the spawning season.

The first experiment.

The eggs were artificially fertilized on Oct. 28, 1927, but were not in good condition, as they were taken shortly after the prime spawning season. When the eggs were transferred into the thermostat two hours after the fertilization, they were found at two-cell stage.

No. 1 —No. 9, having been fairly damaged within 2–5 days afterwards, still showed a fairly good result in the hatching as given in Table 1, whereas No. 10 was perished in 10 days.

(1) T. Higurashi; Optimum water temperature for hatching of the eggs of *Plecoglossus altivelis* T. & S. (Jour. Imp. Fish. Inst. Vol. 20, No. 4; 1925).

(2) T. Higurashi & N. Nakai: The influence of the lower temperature on the development of the eggs of *Plecoglossus altivelis* T. & S. (Jour. Imp. Fish. Inst. Vol. 21, No. 6; 1926).

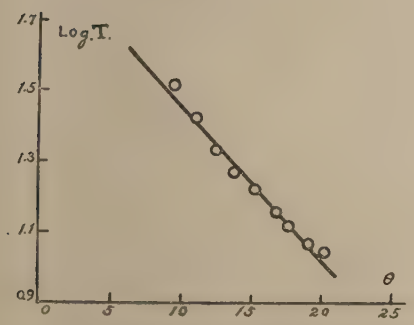
Table 1. The hatching result of the first experiment.

No. of lots.	1	2	3	4	5	6	7	8	9	10
Mean temper. in C. (t)	20.1	19.1	17.7	16.9	15.2	13.9	12.6	11.2	9.5	8.0
Mean variation.	0.2	0.3	0.4	0.5	0.4	0.6	0.5	0.5	0.4	0.2
Number of eggs used.	167	103	86	98	87	127	145	143	60	141
Number of hatched fry.	93	53	48	53	50	70	76	75	28	0
Number of deformity.	3	0	0	0	0	0	2	0	5	—
Percentage of hatching.	55.7	51.5	55.8	54.1	57.5	55.1	52.4	52.4	46.7	0
Percentage of deformity.	3.2	0	0	0	0	0	2.6	0	17.9	—
Hatching period.	6-12/XI	8-12/XI	10-12/XI	11-13/XI	12-16/XI	14-18/XI	7-23/XI	23-26/XI	20/XI-3/XII	—
Mean hatching days (d).	11.0	11.7	13.1	14.3	16.6	18.6	21.5	26.5	32.8	—
Mean variation (m).	1.2	0.9	0.8	0.3	0.5	0.4	1.0	0.1	2.2	—
$\frac{m}{d}\times 100$.	11	8	6	2	3	2	5	0.4	7	—
$d\times t$ in C.	221	224	232	242	252	259	271	297	312	—

Remarks: The percentage of the deformity is calculated to the number of the hatched fry. The mean room-temperature during the experiment was 12.4° C.

Remarkably enough, there was a great resemblance in the result of the hatching of No. 1—No. 8 and the normal hatching took place even at the highest temperature, whereas No. 9 was poorer than the former, showed a somewhat lower percentage in hatching, and higher of the deformity; and none hatched out in No. 10.

Fig. 1



The straight-line relation between the temperature (θ) and the logarithms of hatching days (log. T).

Hence, it may be inferred that the lower limit of the favourable water temperature was No. 8 (11.2 °C.), but the higher one remains undetermined. Between the temperature and the logarithms of hatching days the straight-line relation is held as shown in Fig. 1 and Table 2, and the slope of this line is obtained from the relating formula of $Te^{a\theta}=\text{Const.}$[1] as follows: $a=0.101$ and $Q_{10}=2.7$

(1) T. Higurashi & M. Tauti: On the relation between temperature and the rate of development of fish-eggs. (Jour. Imp. Fish. Inst. Vol. 21, No. 1; 1925).

Table 2. The relation between the temperature and the hatching days in the first experiment.

Mean water temperature in C.	20.1	19.1	17.7	16.9	15.2	13.9	12.6	11.2	9.5	8.0
Mean hatching days (T).	11.0	11.7	13.1	14.3	16.6	18.6	21.5	26.5	32.8	—
Log. T.	1.02	1.06	1.13	1.16	1.23	1.29	1.35	1.41	1.48	—
Calculated hatching days.	10.5	11.6	13.3	14.5	17.2	19.6	22.3	25.7	30.5	35.5

The second experiment.

Notwithstanding the late spawning season, fully matured fishes were caught on Nov. 18 and the eggs were artificially fertilized at 7 p.m. on the same day. When the eggs were transferred into the thermostat 3 hours afterwards, they were at two-cell stage. The temperature in the thermostat should, in view of the result of the first experiment, have been changed, but as no more apparatus was at my disposal, the eggs had to be examined under the same condition as in the previous case.

As to the development, a pretty number of eggs in No. 1—No. 9 were found dead within 2–7 days afterwards, but the rests, suffering no more damage, hatched out normally, whereas No. 10 was annihilated in 10 days.

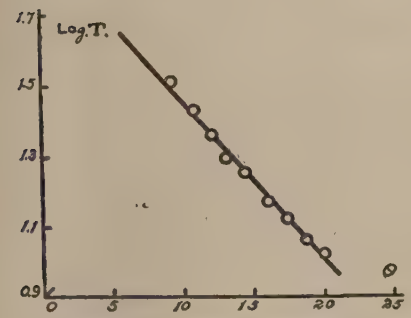
Table 3. The hatching result of the second experiment.

No. of lots.	1	2	3	4	5	6	7	8	9	10
Mean temper. in C. (t).	20.1	18.8	17.3	16.1	14.5	13.2	12.2	10.8	9.3	7.5
Mean variation.	0.3	0.3	0.3	0.3	0.4	0.3	0.4	0.4	0.9	0.3
Number of eggs used.	431	463	492	522	561	503	437	528	486	459
Number of hatched fry.	344	377	406	422	470	409	368	422	271	0
Number of deformity.	11	14	6	9	8	11	15	24	47	—
Percentage of hatching.	79.8	81.4	82.5	80.8	83.8	81.3	84.2	79.9	55.8	0
Percentage of deformity.	3.2	3.7	1.5	2.1	1.7	2.7	4.1	5.7	17.3	—
Hatching period.	27/XI–1/XII	27/XI–2/XII	30/XI–4/XII	1–6/XII	3–11/XII	6–12/XII	8–16/XII	12–21/XII	18–28/XII	—
Mean hatching days (d).	10.6	11.6	13.5	14.7	17.8	19.9	23.0	27.2	32.7	—
Mean variation (m).	0.4	0.6	0.2	0.4	0.9	1.3	1.2	1.5	2.4	—
$\frac{m}{d}\times 100$.	7	5	2	3	5	7	5	6	7	—
$d\times t$ in C.	213	218	234	237	258	263	281	294	304	—

Remarks: The percentage of the deformity is calculated to the number of the hatched fry. The mean room-temperature during the experiment was 14.6° C.

In comparing the present result with the previous one, we find the same tendency in hatching ; namely, the lower limit of the favourable water temperature was still indicated by No. 8 and also the higher one was as yet undetermined.

Fig. 2



The strate-line relation between the temperature (θ) and the logarithms of hatching days (log. T).

Between the temperature and the hatching days the straight-line relation is held as shown in the Fig. 2 and the Table 4 and the slope of this line is nearly equivalent to that of the former experiment, being calculated from the relating formula of $Te^{a\theta}=$Const. as follows: $a=0.105$ and $Q_{10}=2.8$

Accordingly, it is inferred that the range of the favourable water temperature is not variable in this case in accordance with the difference of the spawning season.

Table 4. The relation between the temperature and the hatching days in the second experiment.

Mean temperature in C.	20.1	18.8	17.3	16.1	14.5	13.2	12.2	10.8	9.3	7.5
Mean hatching days (T).	10.6	11.6	13.5	14.7	17.8	19.9	23.0	27.2	32.7	—
Log. T.	1.00	1.06	1.13	1.18	1.26	1.32	1.36	1.43	1.49	—
Calculated hatching days.	10.1	11.5	13.6	15.3	18.1	20.7	23.1	26.6	31.2	39.7

The third experiment.

On Dec. 7, when it was out of the season for spawning, the eggs were taken out from the fishes which still were lingering on the spawning ground : the greater part of eggs were already spawned, and the remainder was not in good condition. Within two hours after the fertilization, the eggs were transferred into two thermostats respectively ; namely, one was the same apparatus as in the previous experiment and the other a new one which maintained the different range of the temperature from that of the former. The eggs were about to enter the two-cell stage at the beginning of this experiment.

Experiment " A."

Using the new thermostat, the eggs were examined at the temperatures

ranging from 23.8°–6.6° C. As the eggs in No. 1—No. 9 were mostly dead within 2–4 days afterwards and No. 10 was perished in 10 days, the hatching result was very poor as shown in the Table 5.

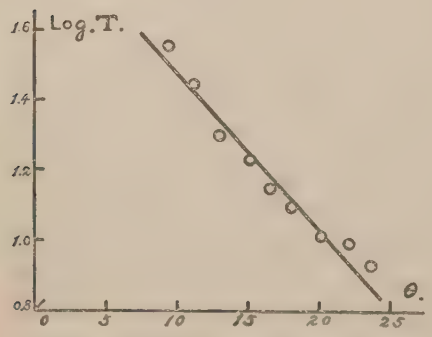
Table 5. The hatching result of the experiment "A."

No. of lots.	1	2	3	4	5	6	7	8	9	10
Mean temper. in C. (t).	23.8	22.0	20.0	18.2	16.6	15.2	13.0	11.3	9.4	6.6
Mean variation.	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.4	0.2
Number of eggs used.	98	166	112	125	212	187	136	123	177	196
Number of hatched fry.	7	23	26	23	51	35	40	35	44	0
Number of deformity.	4	3	1	0	0	1	0	0	16	—
Percentage of hatching.	6.5	13.9	23.2	18.4	24.1	18.7	27.5	28.5	24.9	0
Percentage of deformity.	57.1	13.0	3.8	0	0	2.9	0	0	36.4	—
Hatching period.	15–17/ XII	17–20/ XII	17–20/ XII	19–21/ XII	20–24/ XII	23–27/ XII	26/XII –1/I	31/XII –5/I	9–17/I	—
Mean hatching days (d).	8.5	9.8	10.3	12.5	14.0	17.1	20.1	26.4	36.1	—
Mean variation (m).	0.3	0.5	0.5	0.4	0.9	0.6	0.7	1.8	2.1	—
$\frac{m}{d}\times 100$.	4	5	5	3	6	4	4	7	6	—
$d\times t$ in C.	202	216	206	228	232	260	261	298	339	—

Remarks: The percentage of the deformity is calculated to the number of the hatched fry. The mean room-temperature during the experiment was 17.8° C.

Accordingly, No. 1 showed the poorest result, having the least number of the hatching and the highest percentage of the deformity, and somewhat better result than this was obtained from No. 2. On the other hand, No. 3—No. 8 obtained higher percentages in the hatching than the former with no deformity or but a few, whereas No. 9 showed a great increase in the deformity.

Fig. 3.



The straight-line relation between the temperature (θ) and the logarithms of hatching days (log. T).

Hence, it may be concluded that the favourable water temperature is indicated by No. 3—No. 8, viz. 22.0°–11.3° C., which just corresponds to the limit in the former experiments. As to the temperature and the hatching days, the straight-line relation is held between them and the slope of this line which is almost equivalent to

those of the previous experiments, is calculated from the relating formula of $Te^{a\theta}$=Const. as follows: a=0.103 and Q_{10}=2.8 (See, Fig. 3 and Table 6) Thus it may be inferred the range of the favourable water temperature also in this case is not variable in accordance with the difference of the spawning season.

Table 6. The relation between the temperature and the hatching days in the experiment "A."

Mean temperature in C.	23.8	22.0	20.0	18.2	16.6	15.2	13.0	11.3	9.4	6.6
Mean hatching days (T).	8.5	9.8	10.3	12.5	14.0	17.1	20.1	26.4	36.1	—
Log. T.	0.86	0.94	1.03	1.11	1.18	1.24	1.34	1.42	1.50	—
Calculated hatching days.	7.2	8.7	10.7	12.8	15.2	17.5	22.0	26.2	31.8	42.4

Experiment "B."

In order to ascertain whether the limit of the favourable water temperature may vary in accordance with the difference of the spawning season, a part of the eggs which were used in the experiment "A" were kept at the same temperature as in the first and second experiments. No. 1—No. 9 were greatly damaged within 2-4 days after transferring the eggs into the thermostat and the eggs in No. 10 were almost destroyed in 3-6 days, and the poor result, as in the experiment "A", was also observed in this case.

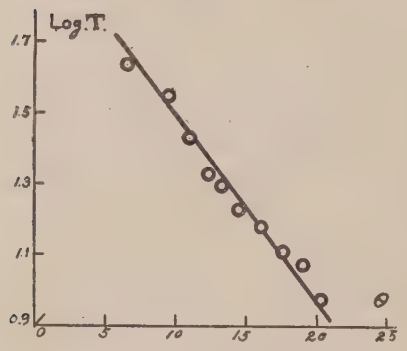
Table 7. The hatching result of the experiment "B."

No. of lots.	1	2	3	4	5	6	7	8	9	10
Mean temper. in C. (t)	20.3	19.1	17.6	16.2	14.5	13.3	12.3	11.0	9.5	6.9
Mean variation.	0.5	0.4	0.5	0.4	0.5	0.5	0.5	0.4	0.4	0.3
Number of eggs used.	58	73	61	34	58	40	37	44	35	90
Number of hatched fry.	10	12	9	7	13	5	5	7	6	4
Number of deformity.	1	0	0	0	0	0	1	1	0	4
Percentage of hatching.	12.2	16.5	14.8	20.6	22.4	12.5	13.5	15.9	17.1	4.4
Percentage of deformity.	10.0	0	0	0	0	0	20.0	14.3	0	100
Hatching period.	17/XII	18-20/XII	20-21/XII	22-23/XII	24-26/XII	27-28/XII	17/XII-1/I	2-5/I	11-13/I	8-29/I
Mean hatching day (d).	9.5	11.7	12.6	15.1	17.0	19.9	21.3	27.2	35.5	44.5
Mean variation (m).	0	1.0	0.2	0.5	0.6	0.5	4.5	1.5	1.0	1.5
$\frac{m}{d}\times 100$.	0	9	2	3	4	3	21	6	3	3
$d\times t$ in C.	193	224	222	245	247	265	262	299	337	304

Remarks: The percentage of the deformity is calculated to the number of the hatched fry. The mean room-temperature during the experiment was 11.7° C.

As the above-mentioned hatching result was very poor and obscured owing to bad quality of the eggs, the exact range of the favourable water temperature could not be determined, but No. 1—No. 9 are, on the whole, to be included within this limit, whereas No. 10 should be treated as exception, for the result of hatching is far inferior than the former. Comparing this with the former experiments, the notable facts are observed in this case; namely, the range of the favourable temperature is extended to No. 9, and a few hatched in No. 10, in which it had never hatched before.

Fig. 4.



The straight-line relation between the temperature (θ) and the logarithms of hatching days (log. T).

Between the temperature and the hatching days, the straight-line relation is held as given on Fig. 4 and Table 8 but the slope of this line, obtained from the relating formula of $Te^{a\theta}$=Const., is somewhat greater than those of the previous experiments: a= 0.121 and Q_{10}=3.3

Accordingly, so far as this expriment goes, it may be recognized that the range of the favourable temperature may, in some extent, vary in accordance with the difference of the spawning season, but it is to be ascertained again.

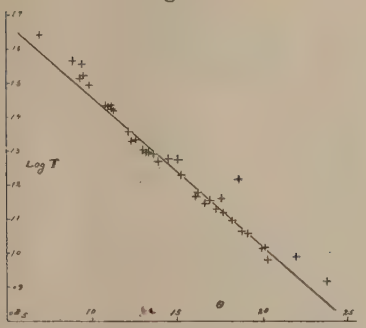
Table 8. The relation between the temperature and the hatching days in the experiment "B."

Mean temperature in C.	20.3	19.1	17.6	16.2	14.5	13.3	12.3	11.0	9.5	6.9
Mean hatching days (T).	9.5	11.7	12.6	15.1	17.0	19.9	21.3	27.2	35.5	44.5
Log. T.	0.98	1.07	1.10	1.18	1.23	1.30	1.33	1.43	1.55	1.64
Calculated hatching days.	9.1	10.5	12.6	15.0	18.4	21.2	23.9	28.0	33.6	45.9

Conclusion.

So far as these experiments concern, the limit of the favourable temperature is about 11°—20° C., but judging from the straight-line relation between the temperature and the hatching days in the combined result with the already reported experiments, it is more proper to recognize the limit of the favourable temperature as being about 12°-20° C. The slope of the straight-line is obtained

Fig. 5.



The straight-line relation between the temperature (θ) and the logarithms of hatching days (log. T.) in the combined result.

from the relating formula of $Te^{a\theta}$=Const. as follows: a=0.101 and Q_{10}=2.7 (See, Fig. 5 and Table 9) As no remarkable difference in the result of the hatching has been observed within the limit of the favourable temperature, the optimum one which Higurashi states is inaccurate. Whether the range of the favourable temperature may vary in accordance with the difference of the spawning season is doubtful, and it requires the pursuit of further study.

Table 9. The combined result of the relation between the temperature and the hatching days in the experiments in 1924, '25 and '27.

Mean temp. in C.	Hatch. number.	Mean hatch. days (T).	Log. T.	Calcul. hatch. days.	Mean temp. in C.	Hatch. number.	Mean hatch. days (T).	Log. T.	Calcul. hatch. days.
23.8	7	8.5	0.93	7.1	13.9	70	18.6	1.27	19.3
22.0	23	9.8	0.99	8.5	13.6	75	19.6	1.29	19.9
20.3	10	9.5	1.00	10.1	13.3	5	19.9	1.30	20.5
20.1	449	10.4	1.02	10.3	13.2	409	19.9	1.30	20.7
20.0	26	10.3	1.01	10.4	13.0	40	20.1	1.30	21.2
19.1	64	11.5	1.06	11.4	12.6	76	21.5	1.33	22.0
18.8	377	11.6	1.06	11.9	12.3	5	21.3	1.33	22.7
18.6	1	16 5	1.22	12.0	12.2	429	22.8	1.36	22.9
18.2	23	12.5	1.10	12.5	11.3	35	26.4	1.42	25.1
17.7	48	13.1	1.12	13.2	11.2	75	26.5	1.42	25.4
17.6	1	14.5	1.16	13.3	11.1	31	27.8	1.44	25.6
17.3	406	13.5	1.13	13.7	11.0	7	27.2	1.43	25.9
16.9	53	14.3	1.16	14.3	10.8	422	27.2	1.43	26.4
16.6	51	14.0	1.15	14.7	9.8	54	31.4	1.45	29.2
16 2	7	15.1	1.18	15.3	9.5	34	33.3	1.52	30.1
16.1	422	14.7	1.17	15.5	9.4	44	36.1	1.56	30.4
15.2	84	16.9	1.23	16.9	9.3	271	32.7	1.51	30.7
15.0	4	19.0	1.28	17.3	8.9	17	37.1	1.57	32.0
14.5	483	19.0	1 28	18.2	6.9	4	44.0	1.64	39.2

Summary.

1. The range of the favourable water temperature for the hatching of eggs of *Plecoglossus altivelis* is approximately 12°–20° C.

2. Between the temperature and the logarithms of hatching days, the straight-line relation is held and the slope of this line is obtained from the relating formula of $Te^{a\theta}$=Const. as follows: a=0.101 and Q_{10}=2.7

3. The relation between the temperature and the hatching days is as follows:

Mean temperature in C.	20.0	19.0	18.0	17.0	16.0	15.0	14.0	13.0	12.0	11.0
Mean hatching days (T).	10.4	11.5	12.8	14.1	15.6	17.3	19.1	21.2	23.4	25.9
Log. T.	1.02	1.06	1.11	1.15	1.19	1.24	1.28	1.33	1.37	1.41

Remark: This is calculated from the Table 9.

4. Whether the range of the favourable water temperature may vary in accordance with the difference of the spawning season is doubtful, and it requires the pursuit of further study.

POPULATION GROWTH OF THE WATER-FLEA, *MOINA MACROCOPA* STRAUSS.

By

Arata Terao and Tomozô Tanaka.

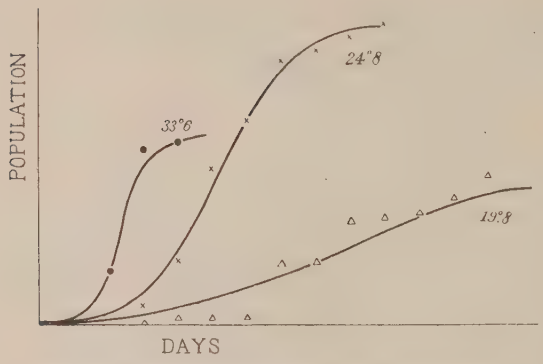
Through the courtesy of Dr. M. Tauti we had at our disposal a Senô-Tauti's serial incubator, in three compartments of which, maintaining 19°.8±0.6, 24°.8±0.6, and 33°.6±0.2 respectively, we put vials with one vigorous parthenogenetic water-flea in each. The experimental animals were given daily 15 c.c. of fresh food-water which was turbid and greenish in colour due to the presence of unicellular organisms which were kindly identified by Prof. M. Higashi to be mostly *Scenedesmus*. Counts were made once a day of all the live water-fleas, which were then separated from dead ones and exuviae. Remarkably enough, they underwent population growth with different maxima at different temperatures, as shown in Table I and Figure 1.

Table I. Population growth of the water-flea at different temperatures.

Temp.	19°.8±0.6		24°.8±0.6		33°.6±0.2	
x / y	Obs.	Calc.	Obs.	Cal.	Obs.	Cal.
0	1.0	6.49	1.0	3.00	1.0	1.00
1	1.0	9.45	3.0	7.73	11.5	10.46
2	6.5	13.67	3.0	19.56	82.3	82.30
3	6.5	19.47	22.5	47.49	249.0	224.34
4	10.5	27.77	94.0	105.10	266.8	266.80
5	10.5	38.73	222.5	196.82		
6	39.5	52.88	296.0	195.80		
7	90.0	70.29	379.5	367.06		
8	90.5	90.51	389.0	404.32		
9	155.5	112.42	413.5	420.72		
10	166.5	134.52	431.0	427.38		
11	167.5	155.27				
12	187.5	173.26				
13	215.0	188.25				

The simplest form of the logistic curve was fitted to the observations, and the approximate values of the constants were as follows

Fig. 1



Showing population growth of the water-flea at different temperatures.

$$y=\frac{229.8322}{1+e^{3.5378-0.3883x}} \quad (19°.8\pm0.6)$$

$$y=\frac{431.6334}{1+e^{4.9620-0.9571x}} \quad (24°.8\pm0.6)$$

$$y=\frac{272.0317}{1+e^{5.6022-2.3835x}} \quad (33°.6\pm0.2)$$

where y denotes number of the water-fleas and x time in days.

INFLUENCE OF TEMPERATURE UPON THE RATE OF REPRODUCTION IN THE WATER-FLEA, *MOINA MACROCOPA* STRAUSS.

By

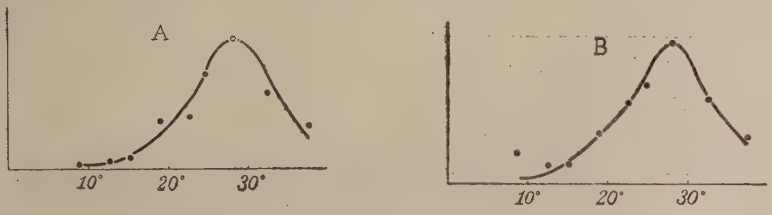
Arata Terao and Tomozô Tanaka.

The water-fleas were found dead within 40 minutes' exposure to a temperature 42° C. The parthenogenetic adults could not live a day at a temperature 39° C, though their offsprings could live more than a day at such warmth. The lower limit of temperature for parthenogenesis of the water-flea, it was found, was about 8° C.

Table I. Rate of reproduction of the water-flea at different temperatures.

Temp.	3°.2± 0.4	8 .7± 0.5	12°.7± 0.6	14°.9± 1.6	18°.9± 0.5	22°.4± 0.7	25°.0± 0.5	28°.1± 0.4	32°.7± 0.2	37°.9± 0.3
Total num. of births.	0	4	17	25	159	110	352	406	112	92
Female days		17	16	19	26	17	30	25	13	16
Births per female day	0	0.235	1.063	1.316	6.115	6.471	11.703	16.240	8.462	5.125
Average of births on record	0	4.0	2.1	2.4	6.5	9.8	12.2	17.4	10.2	5.8

Fig. 1. Showing the rate of reproduction of the water-flea; *A*, births per female day; *B*, average birth on record.



It may be mentioned that the relative values of the rates of reproduction of the water-flea at different temperatures almost tallied with those of the maxima of the population growth at corresponding temperatures.

INFLUENCE OF POPULATION DENSITY UPON THE RATE OF REPRODUCTION IN THE WATER-FLEA, *MOINA MACROCOPA* STRAUSS.

By

Arata Terao and Tomozô Tanaka.

Although far from being complete, our data on this experiment, as shown in Table I and Fig. 1, satisfied the equation

$$y = a\,x^{b}$$

where y represents births per female day, x density of population.

Fig. 1. Showing influence of population density upon the rate of reproduction.

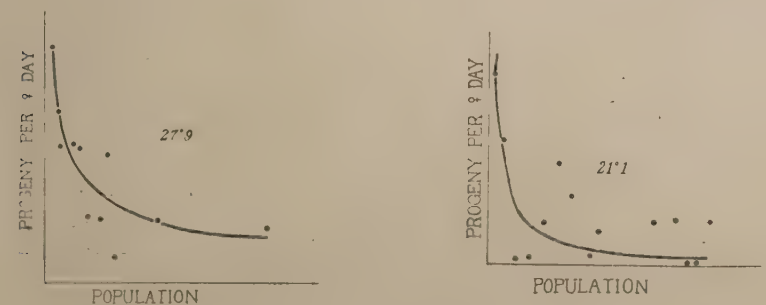


Table I. Influence of population density upon the rate of reproduction.

Temp.	27°.9±0.7									
Population density	1	2	4	5	6	8	9	10	16	32
Total num. of births	121	99	245	49	29	113	171	19	144	125
Birth per ♀ day	17.29	9.90	10.21	9.80	4.83	4.71	9.50	1.90	4.50	3.91

Temp.	21°.1±0.8														
Population density	1	2	4	6	7	8	10	12	15	16	24	27	29	30	32
Total num. of births	28	99	43	3	5	103	74	61	13	126	77	89	9	14	216
Birth per ♀ day	14.0	8.25	3.58	0.5	0.71	3 22	7.40	5.08	0.86	2.63	3.21	3.30	0.31	0.47	3.38

Computing the approximate values of the constants, we have

$$y=17.48\,x^{-0.474} \qquad (27°.9)$$

$$y=15.58\,x^{-0.917} \qquad (21°.1)$$

INFLUENCE OF POPULATION DENSITY UPON THE EGG-LAYING ON THE FISH, *ORYZIAS LATIPES* T. & S.

By

Arata Terao and Tomozô Tanaka.

As given in Table I, our result stood in harmony with those already got in other organisms and the approximate values of the constants were as follows :

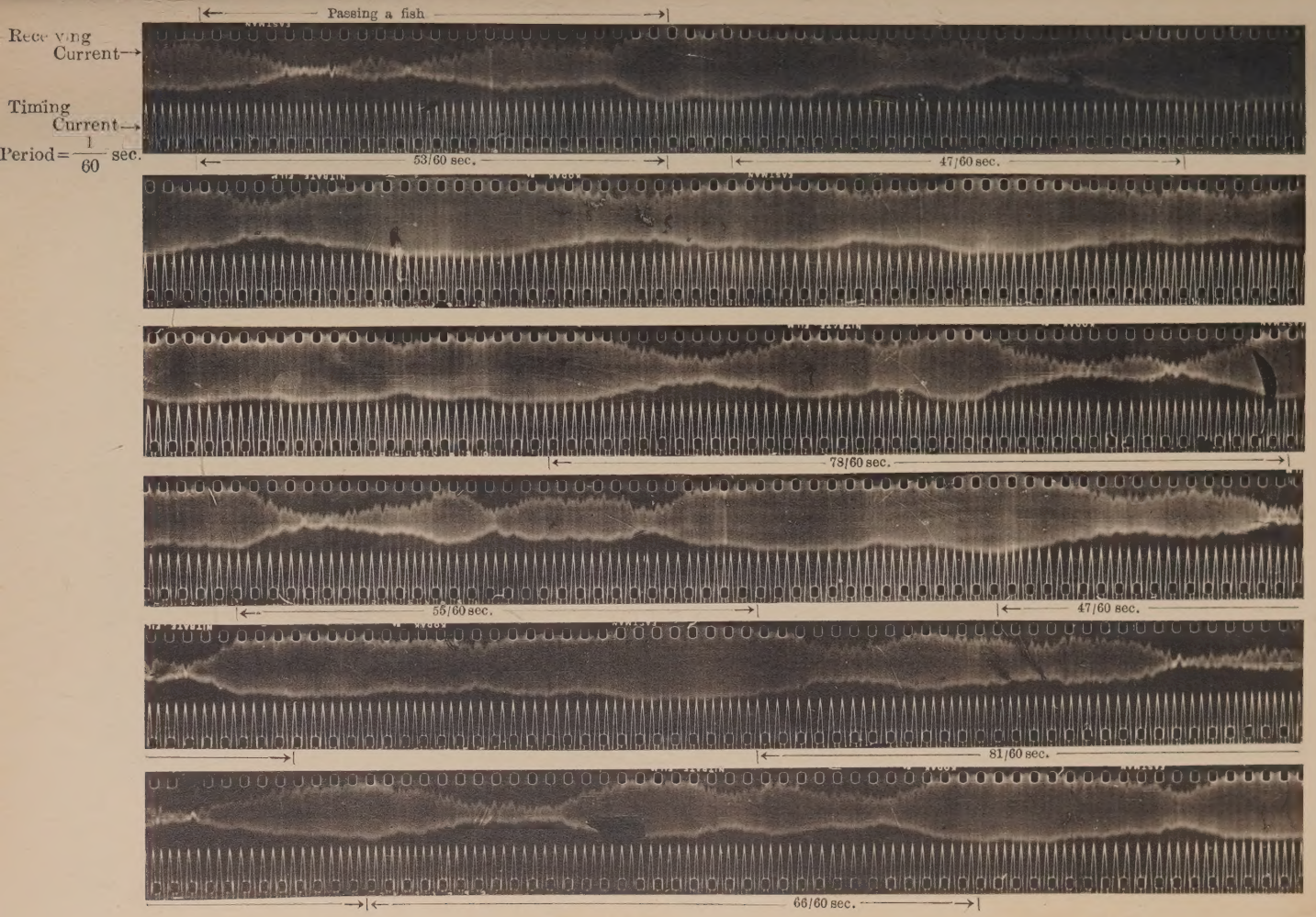
$$y=4.87\,x^{-0.724}$$

where y represents the number of the eggs per female day, x the population density in pairs.

Table I. Influence of population density upon the egg-laying.

Eggs \ Pair	1	2	4	8	16	32
Total	438	273	107	290	193	66
Per pair a day	4.867	3.033	1.783	2.433	0.804	0.138

Fig. 1. Showing influence of population density upon the egg-laying.



Continuous sections of an oscillographic record

Timing Current ——→

Perion = $\frac{1}{60}$ sec.

Receiving Current ——→